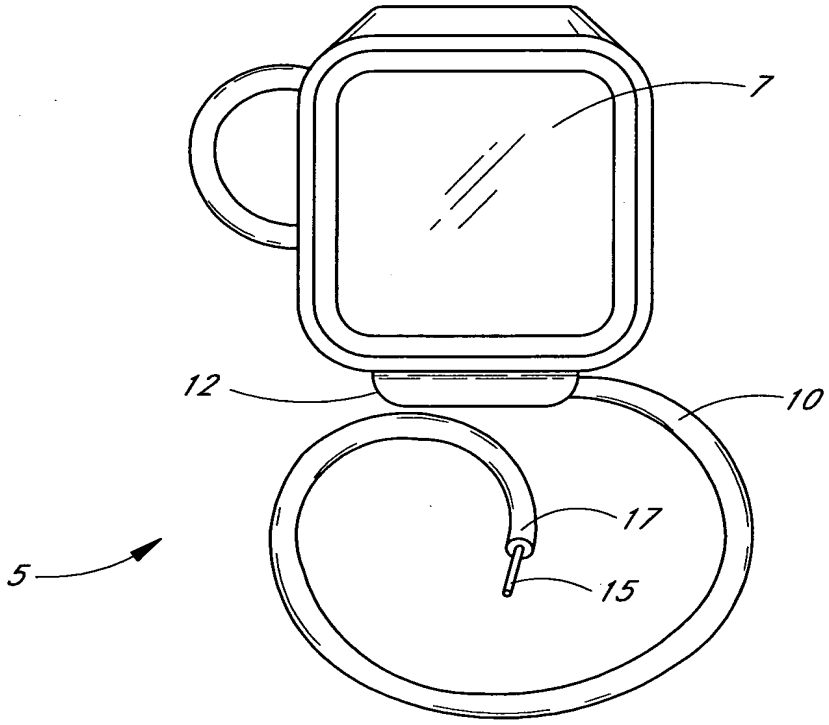


FIG. 1

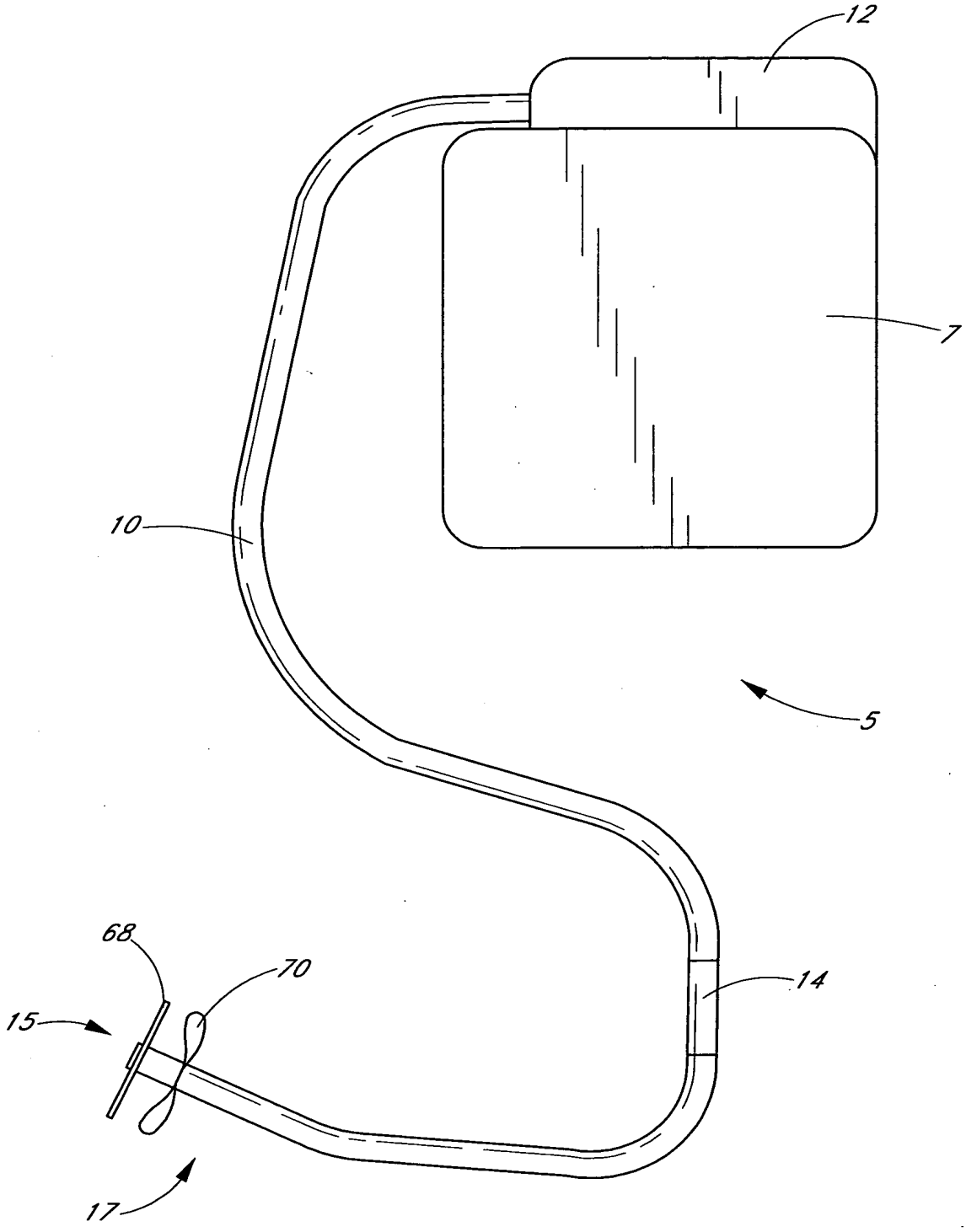


FIG. 2

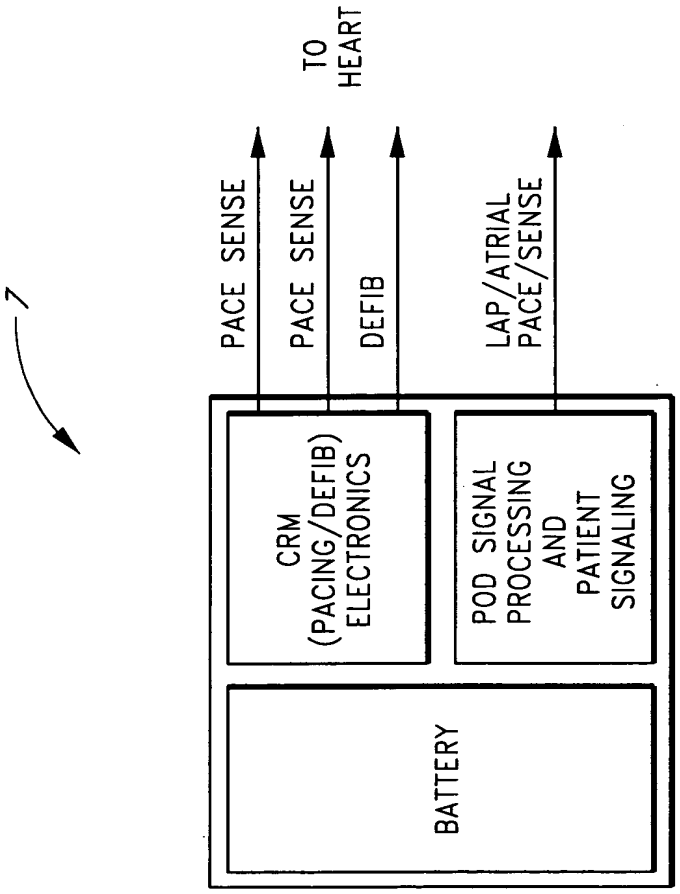

7
TO HEART
PACE SENSE
PACE SENSE
DEFIB
LAP/ATRIAL PACE/SENSE
CRM (PACING/DEFIB) ELECTRONICS
POD SIGNAL PROCESSING AND PATIENT SIGNALING
BATTERY

FIG. 3

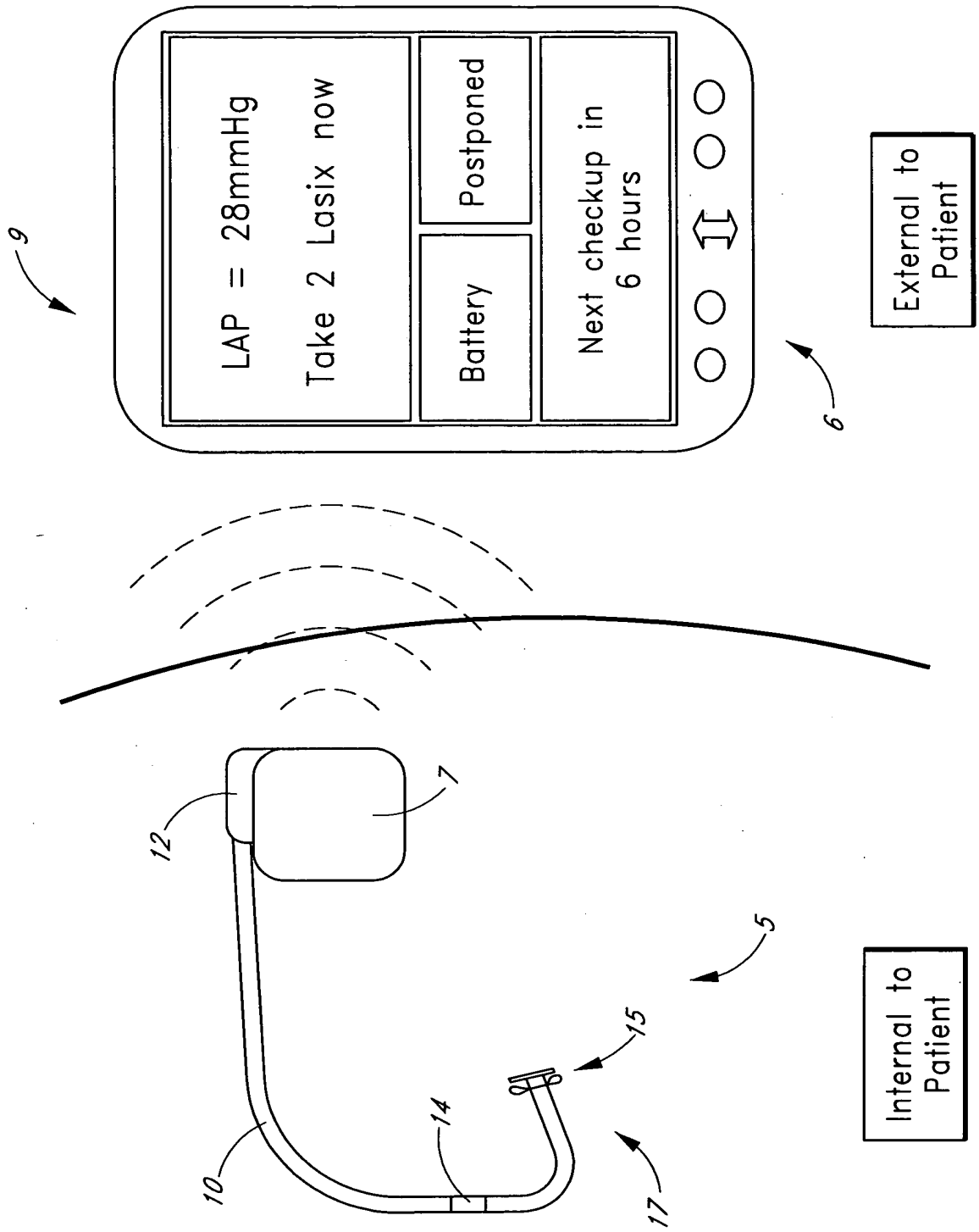

LAP = 28mmHg
Take 2 Lasix now
Postponed
Battery
Next checkup in
6 hours
9
6
External to
Patient
12
7
5
15
14
10
17
Internal to
Patient

FIG. 4

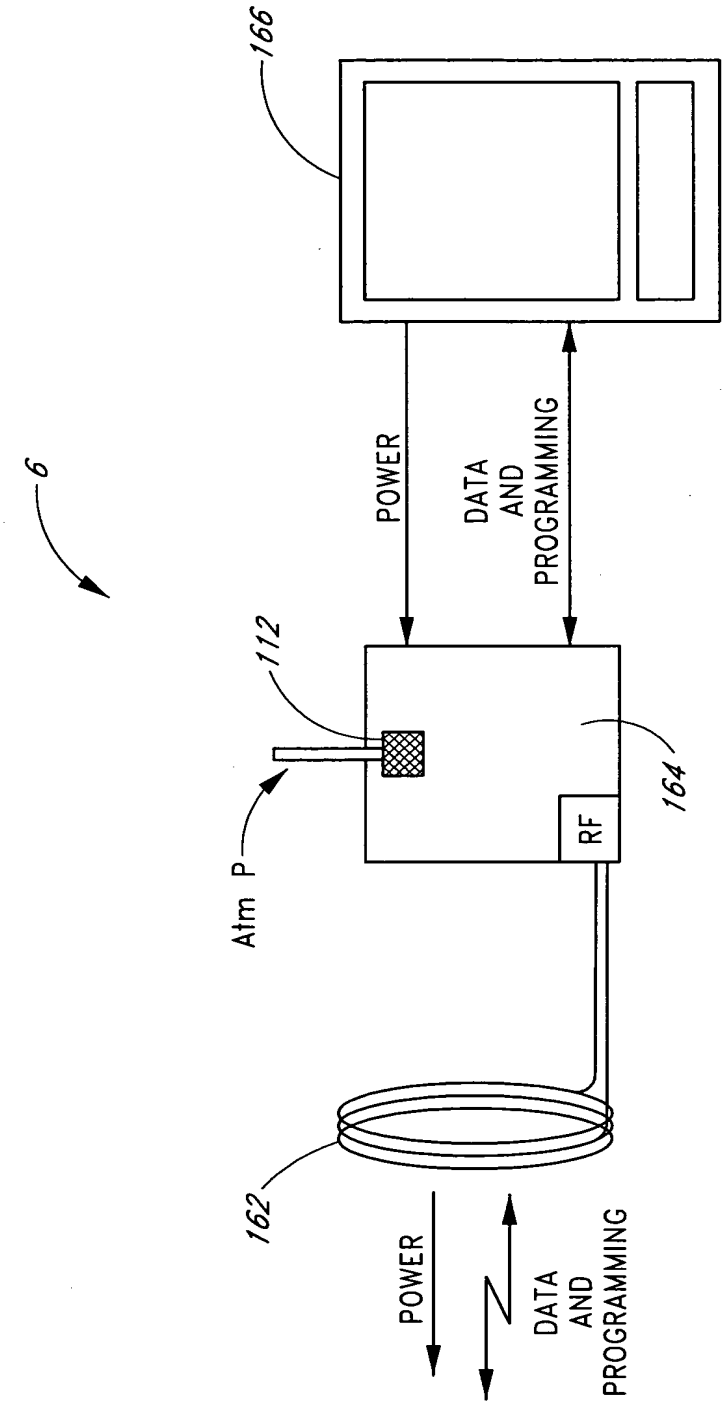

166
6
POWER
DATA AND PROGRAMMING
112
164
RF
Atm P
162
POWER
DATA AND PROGRAMMING

FIG. 5

Right Atrial Pressure Waveforms *FIG. 6A*

Low mean atrial pressure
1. Hypovolemia
2. Improper zeroing of the transducer

Elevated mean atrial pressure
1. Intravascular volume overload states
2. Right ventricular failure due to valvular disease (tricuspid or pulmonic stenosis or regurgitation)
3. Right ventricular failure due to myocardial disease (right ventricular ischemia, cardiomyopathy)
4. Right ventricular failure due to left heart failure (mitral stenosis/regurgitation, aortic stenosis/regurgitation, cardiomyopathy, ischemia)
5. Right ventricular failure due to increased pulmonary vascular resistance (pulmonary embolism, chronic obstructive pulmonary disease, primary pulmonary hypertension)
6. Pericardial effusion with tamponade physiology
7. Obstructive atrial myxoma

Elevated *a* wave (any increase to ventricular filling)
1. Tricuspid stenosis
2. Decreased ventricular compliance due to ventricular failure, pulmonic valve stenosis, or pulmonary hypertension

Cannon *a* wave
1. Atrial-ventricular asynchrony (atria contract against a closed tricuspid valve, as during complete heart block following premature ventricular contraction, during ventricular tachycardia, with ventricular pacemaker)

Absent *a* wave
1. Atrial fibrillation or atrial standstill
2. Atrial flutter

Elevated *v* wave
1. Tricuspid regurgitation
2. Right ventricular heart failure
3. Reduced atrial compliance (restrictive myopathv)

a wave equal to *v* wave
1. Tamponade
2. Constrictive pericardial disease
3. Hypervolemia

Prominent *x* descent
1. Tamponade
2. Subacute constriction and possibly chronic constriction
3. Right ventricular ischemia with preservation of atrial contractility

Prominent *y* descent
1. Constrictive pericarditis
2. Restrictive myopathies
3. Tricuspid regurgitation

Blunted *x* descent
1. Atrial fibrillation
2. Right atrial ischemia

Blunted *y* descent
1. Tamponade
2. Right ventricular ischemia
3. Tricuspid stenosis

Miscellaneous abnormalities
1. Kussmaul's sign (inspiratory rise or lack of decline in right atrial pressure)-constrictive pericarditis, right ventricular ischemia
2. Equalization ($\leq$5 mm Hg) of mean right atrial, right ventricular diastolic, pulmonary artery diastolic, pulmonary capillary wedge, and pericardial pressures in tamponade
3. M or W patterns: right ventricular ischemia, pericardial constriction, congestive heart failure
4. Ventricularization of the right atrial pressure: severe tricuspid regurgitation
5. Saw tooth pattern: atrial flutter
6. Dissociation between pressure recording and intracardiac ECG: Ebstein's anomaly

Left Atrial Pressure/Pulmonary Capillary Wedge Pressure Waveforms

Low mean atrial pressure
1. Hypovolemia
2. Improper zeroing of the transducer

Elevated mean atrial pressure
1. Intravascular volume overload states
2. Left ventricular failure due to valvular disease (mitral or aortic stenosis or regurgitation)
3. Left ventricular failure due to myocardial disease (ischemia or cardiomyopathy)
4. Left ventricular failure due to systemic hypertension
5. Pericardial effusion with tamponade physiology
6. Obstructive atrial myxoma

Elevated *a* wave (any increase to ventricular filling)
1. Mitral stenosis
2. Decreased ventricular compliance due to ventricular failure, aortic valve stenosis, or systemic hypertension

Cannon *a* wave
1. Atrial-ventricular asynchrony (atria contract against a closed mitral valve, as during complete heart block following premature ventricular contraction, during ventricular tachycardia, with ventricular pacemaker)

Absent *a* wave
1. Atrial fibrillation or atrial standstill
2. Atrial flutter

Elevated *v* wave
1. Mitral regurgitation
2. Left ventricular heart failure
3. Ventricular septal defect

a wave equal to *v* wave
1. Tamponade
2. Constrictive pericardial disease
3. Hypervolemia

Prominent *x* descent
1. Tamponade
2. Subacute constriction and possibly chronic constriction
3. Right ventricular ischemia with preservation of atrial contractility

Prominent *y* descent
1. Constrictive pericarditis
2. Restrictive myopathies
3. Mitral regurgitation

Blunted *x* descent
1. Atrial fibrillation
2. Atrial ischemia

Blunted *y* descent
1. Tamponade
2. Ventricular ischemia
3. Mitral stenosis

Pulmonary capillary wedge pressure not equal to left ventricular end-diastolic pressure
1. Mitral stenosis
2. Left atrial myxoma
3. Cor triatriatum
4. Pulmonary venous obstruction
5. Decreased ventricular compliance
6. Increased pleural pressure
7. Placement of cath ter in a nondependent zone of lung

FIG. 6B

Pulmonary Artery Pressure Waveforms

Elevated systolic pressure
1. Primary pulmonary hypertension
2. Mitral stenosis or regurgitation
3. Congestive heart failure
4. Restrictive myopathies
5. Significant left to right shunt
6. Pulmonary disease (pulmonary embolism, chronic obstructive pulmonary disease)

Reduced systolic pressure
1. Hypovolemia
2. Pulmonary artery stenosis
3. Sub- or supravalvular stenosis
4. Ebstein's anomaly
5. Tricuspid stenosis
6. Tricuspid atresia

Reduced pulse pressure
1. Right heart ischemia
2. Right ventricular infarction
3. Pulmonary embolism
4. Tamponade

Bifid pulmonary artery waveform
1. Large left atrial *v* wave transmitted backward (i.e., MR)

Pulmonary artery diastolic pressure greater than pulmonary capillary wedge pressure
1. Pulmonary disease
2. Pulmonary embolus
3. Tachycardia

FIG. 6C

PARAMETERS MEASURED	Mean			Respiratory Component		Cardiac Component		Intracardiac ECG			Core Temp
DIAGNOSIS	RA	LA	RA-LA	RA	LA	RA	LA	HR	Rhythm	ST segment	
Cardiac hemodynamics											
CHF -compensated	⇕	⇕	⇕								
CHF-mild	↑	↑	↑				↑↑	↑			↑
CHF-moderate	↑↑	↑↑	↑↑				↑↑↑	↑			↑
CHF - severe	↑↑↑ ↔	↑↑↑ →	↑↑↑ →	↑↑	↑↑		↑↑↑	↑			↑
CHF- overtreated	↔	→	→								
CHF - mitral regurgitations							↑↑				
CHF-rapid onset	↑↑↑ ↓↓	↑↑↑ ↓↓	↑↑↑ ↓↓					↑			
CHF- acute mitral regurgitations	↑↑↑ ↓↓	↑↑↑ ↓↓	↑↑↑ ↓↓				↑↑↑				
Cardiac tamponade	↑↑	↑↑	≤0			Blunted y-descent		↑		∪ alternans	
Myocardial ischemia	↑	≥↑	≥↑						SR	↑↓	
Cardiac rhythm											
Normal Sinus Rhythm								50-100	SR		
Sinus Tachycardia								>100	SR		
Sinus Bradycardia								<50	SR		
Supraventricular Tachycardia								>120	Reg QRS <110 msec		
Atrial Fibrillation - controlled								60-100	Irreg, no p-wave		
Atrial Fibrillation - rapid								>100	Irreg, no p-wave		
Ventricular Tachycardia						Cannon a-waves	Cannon a-waves	>120	Reg QRS >110 msec: AV dissociation		
Complete Heart Block						Cannon a-waves	Cannon a-waves	<50	AV dissociation		
Non cardiac											
Respiratory Distress	⇕↑	⇕↑	⇕↑	↑↑	↑↑			↑			
hyperthermia											↑↑
hypothermia											↓↓

FIG. 7

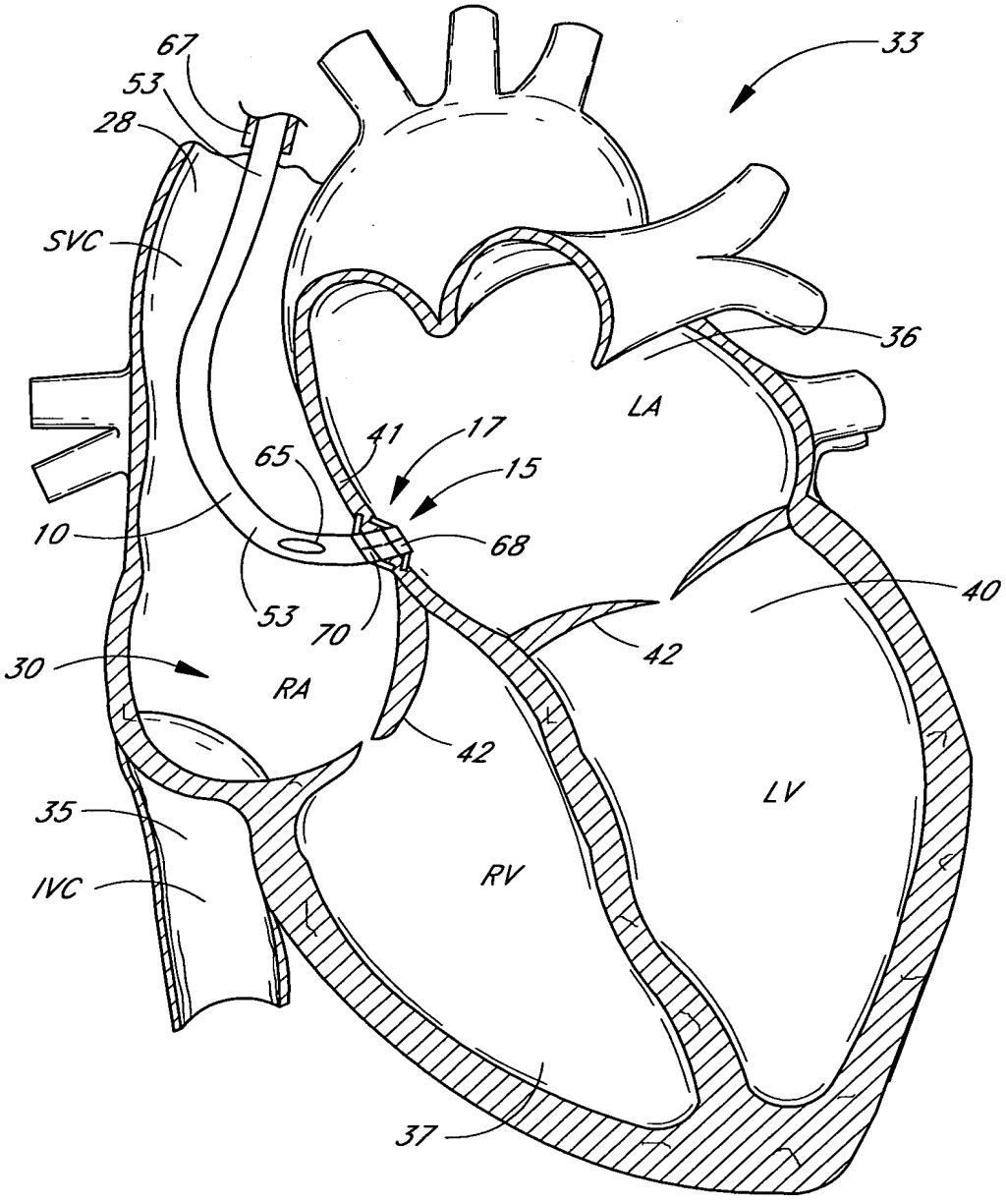

67
53
28
33
SVC
36
LA
41
17
65
15
10
68
40
53
70
42
30
RA
42
LV
35
RV
IVC
37

FIG. 8

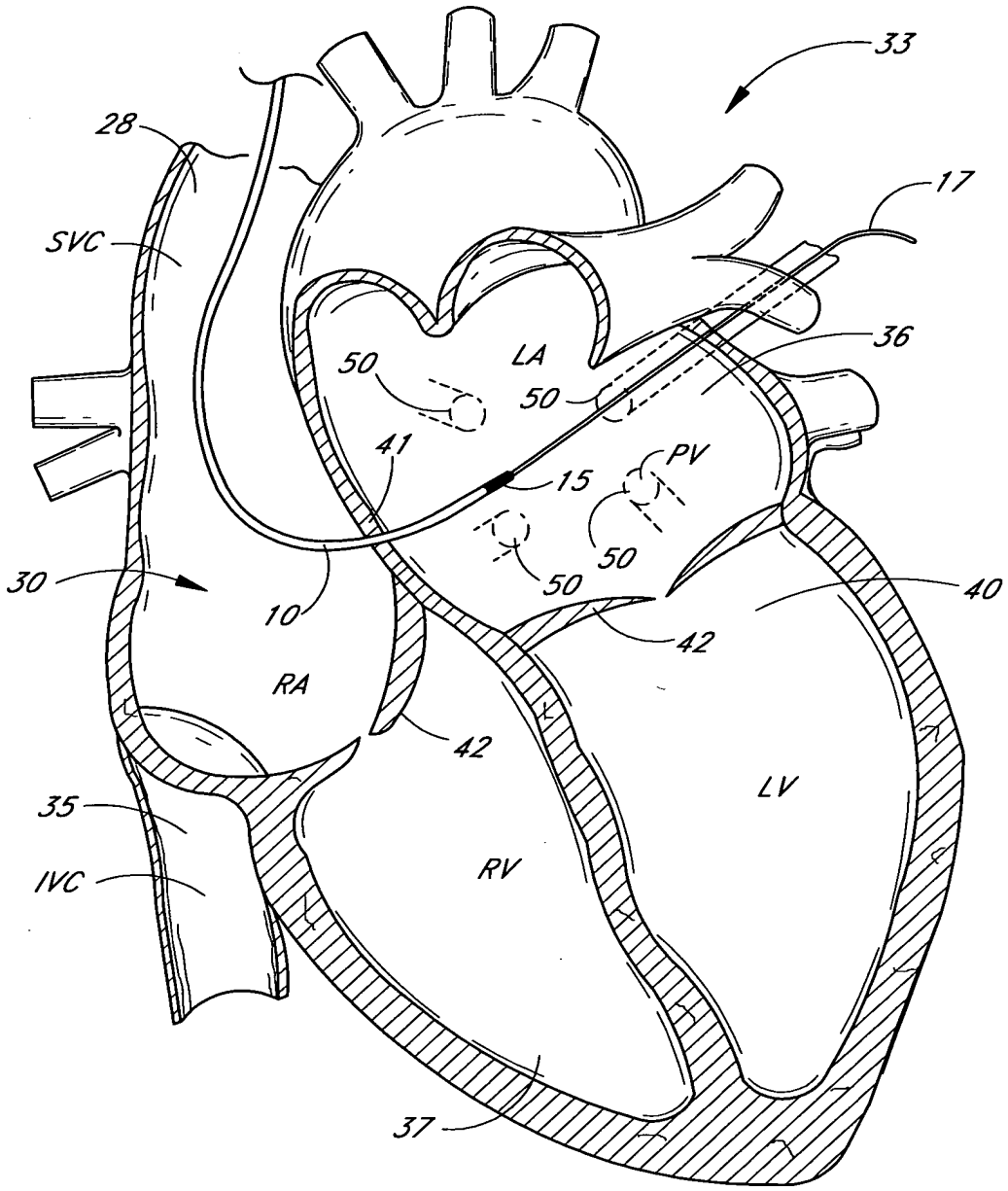

33
28
17
SVC
36
50
LA
50
41
PV
15
50
50
30
10
40
42
RA
42
35
LV
IVC
RV
37

FIG. 9

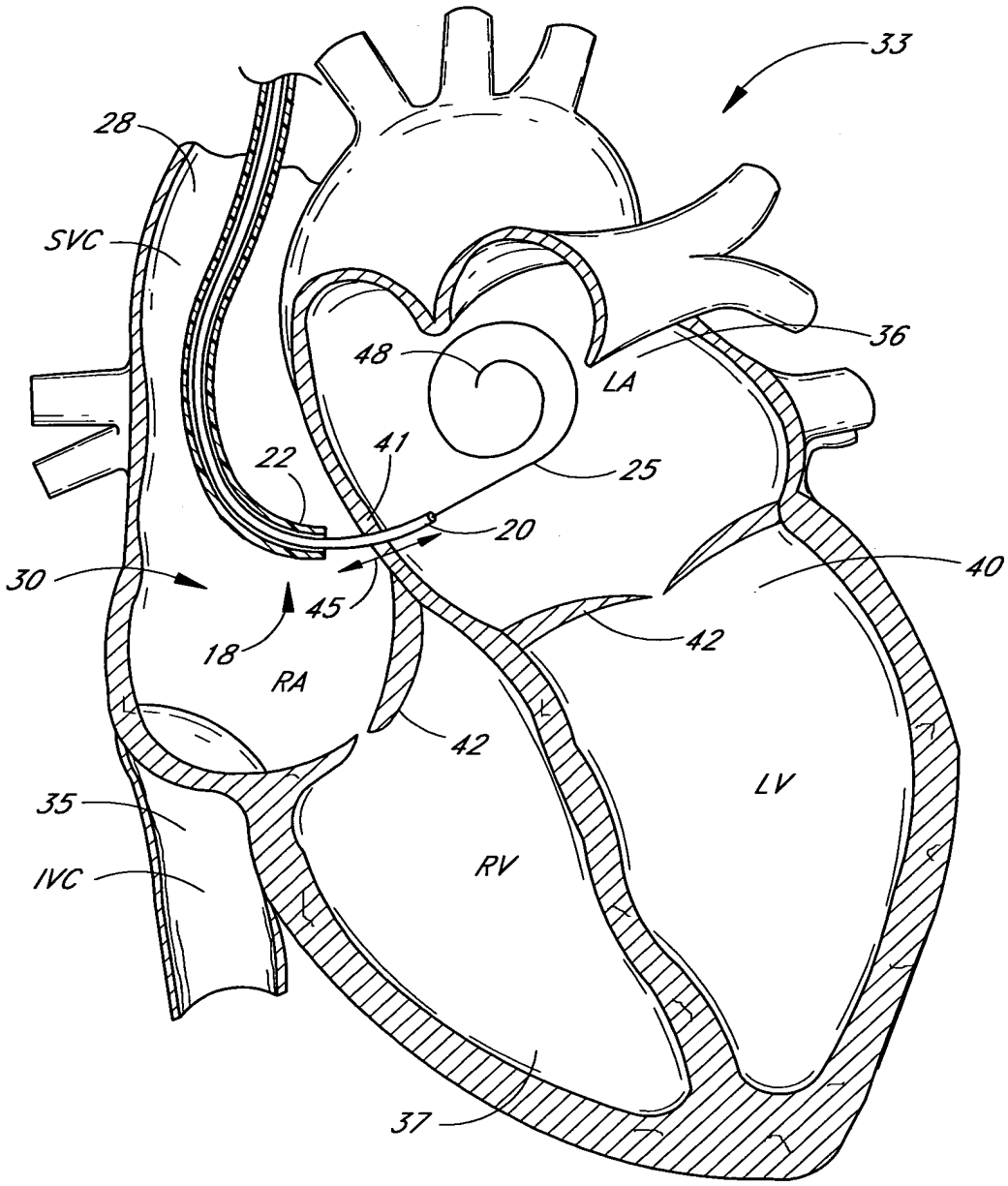


FIG. 10

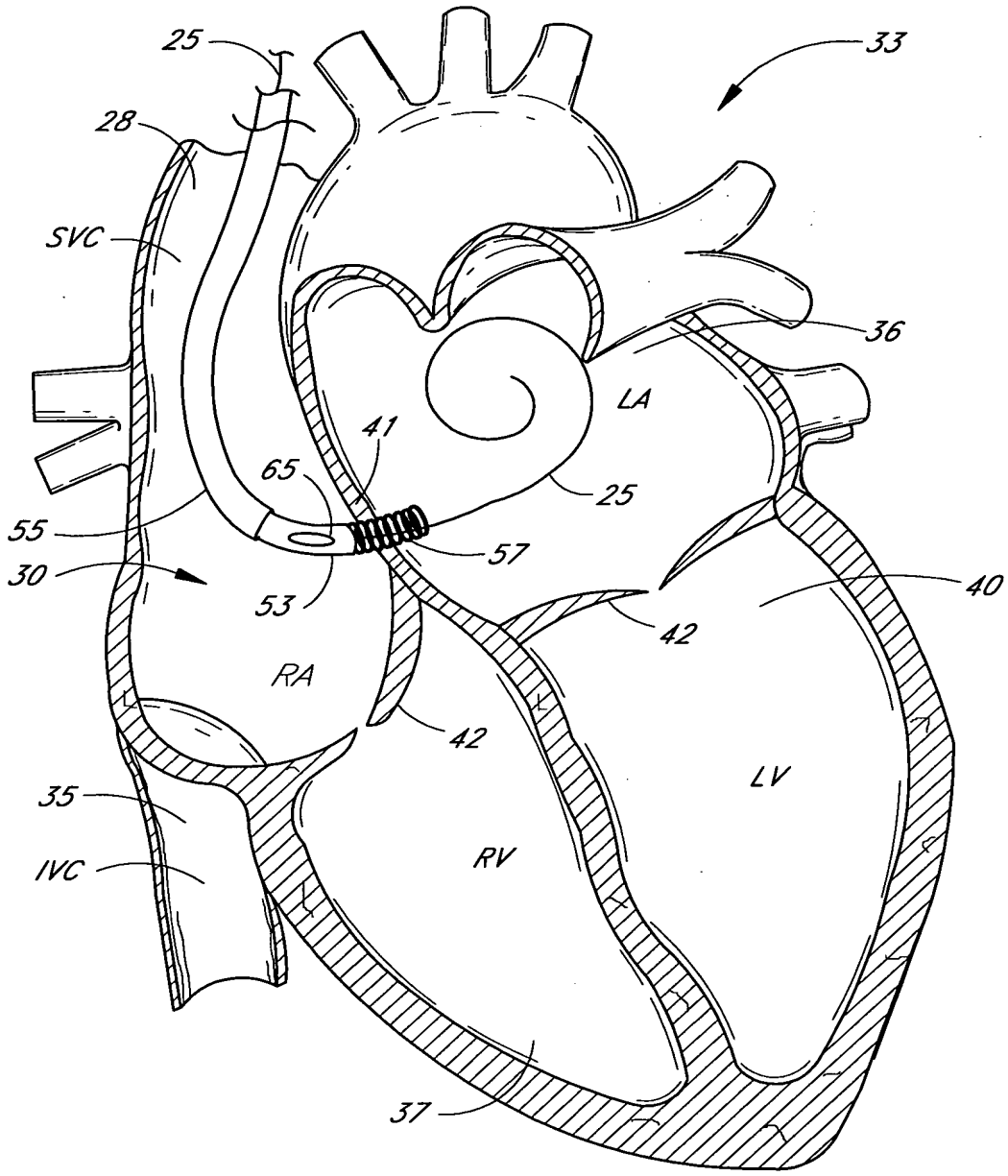


FIG. 11

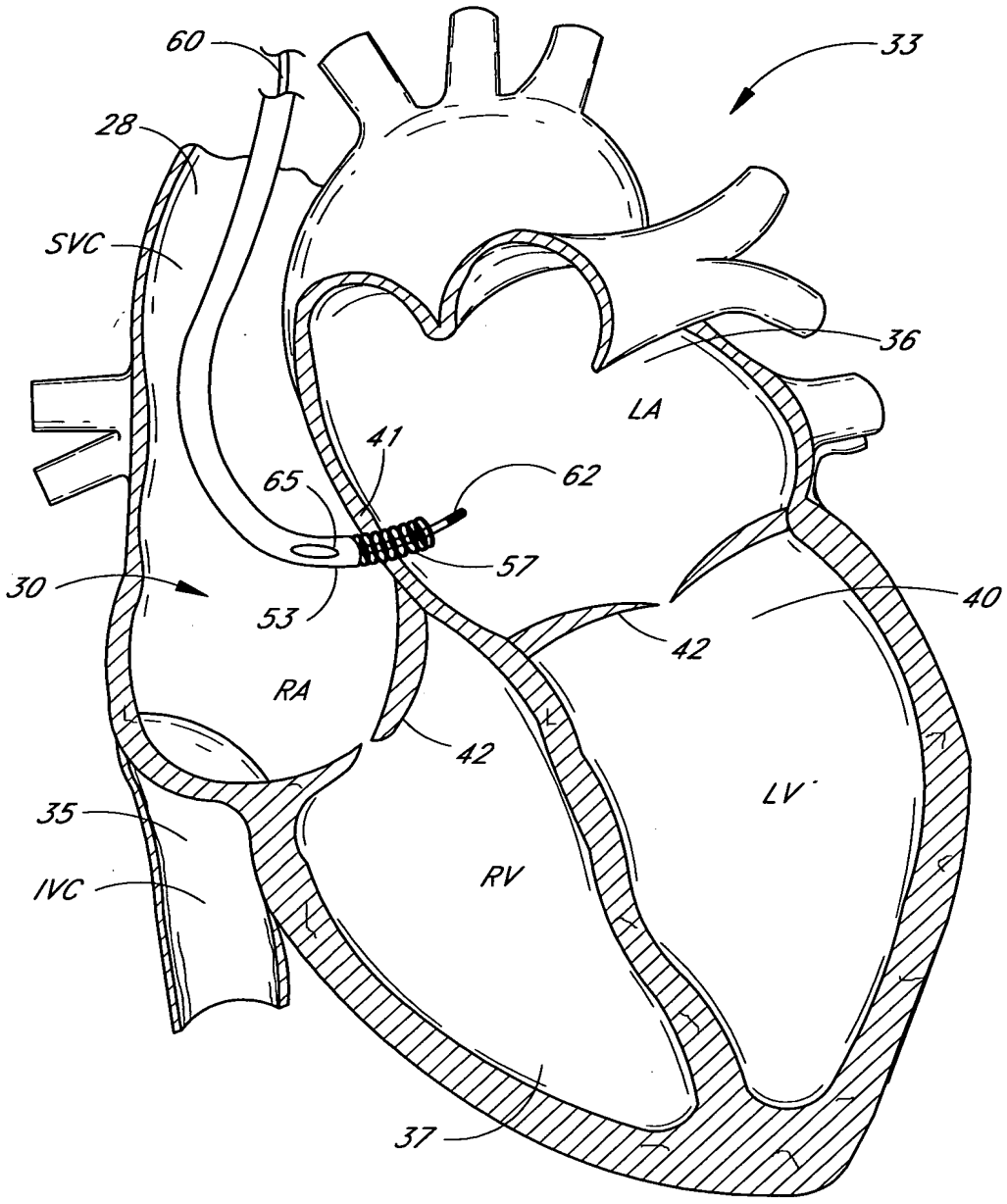


FIG. 12

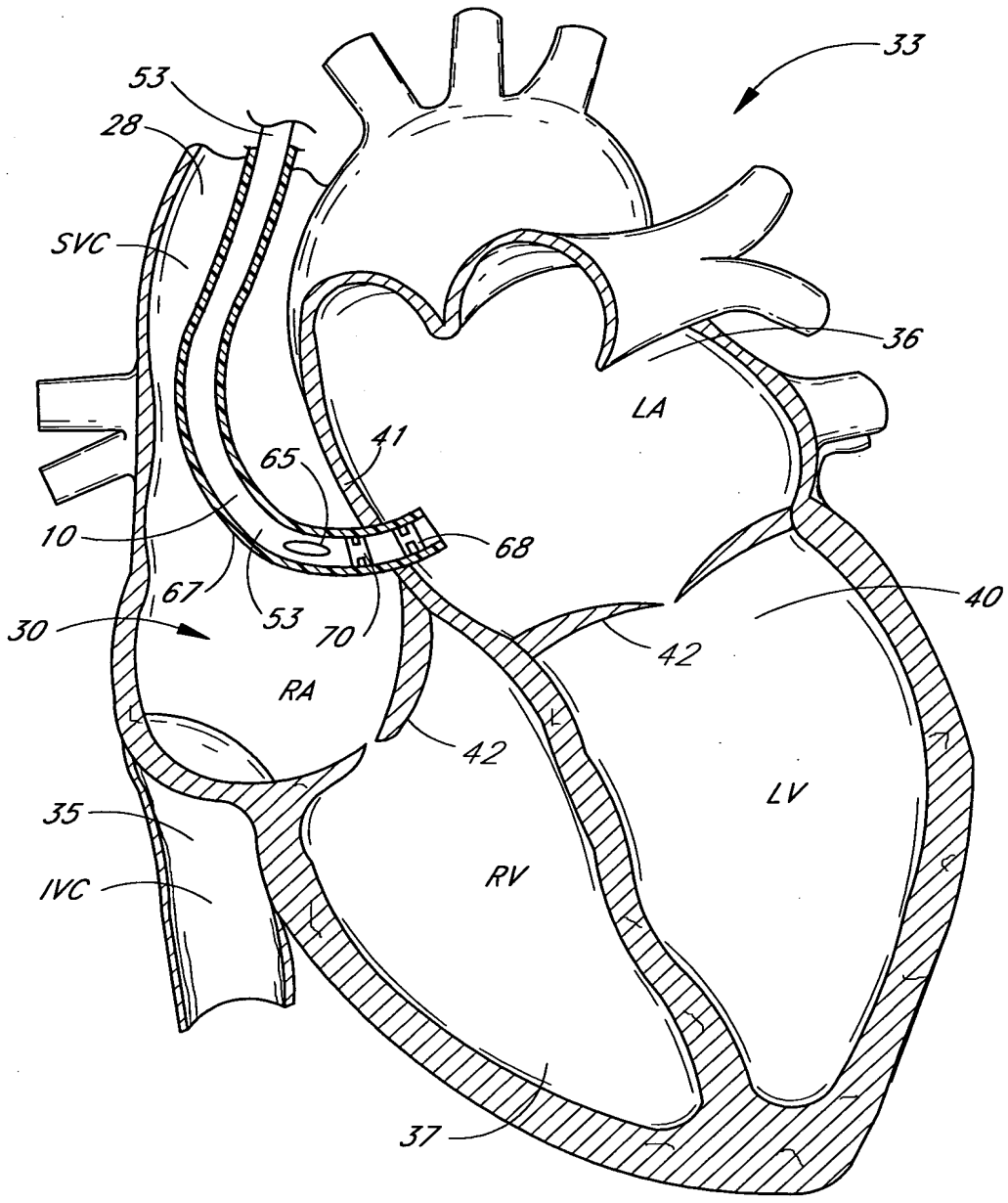


FIG. 13

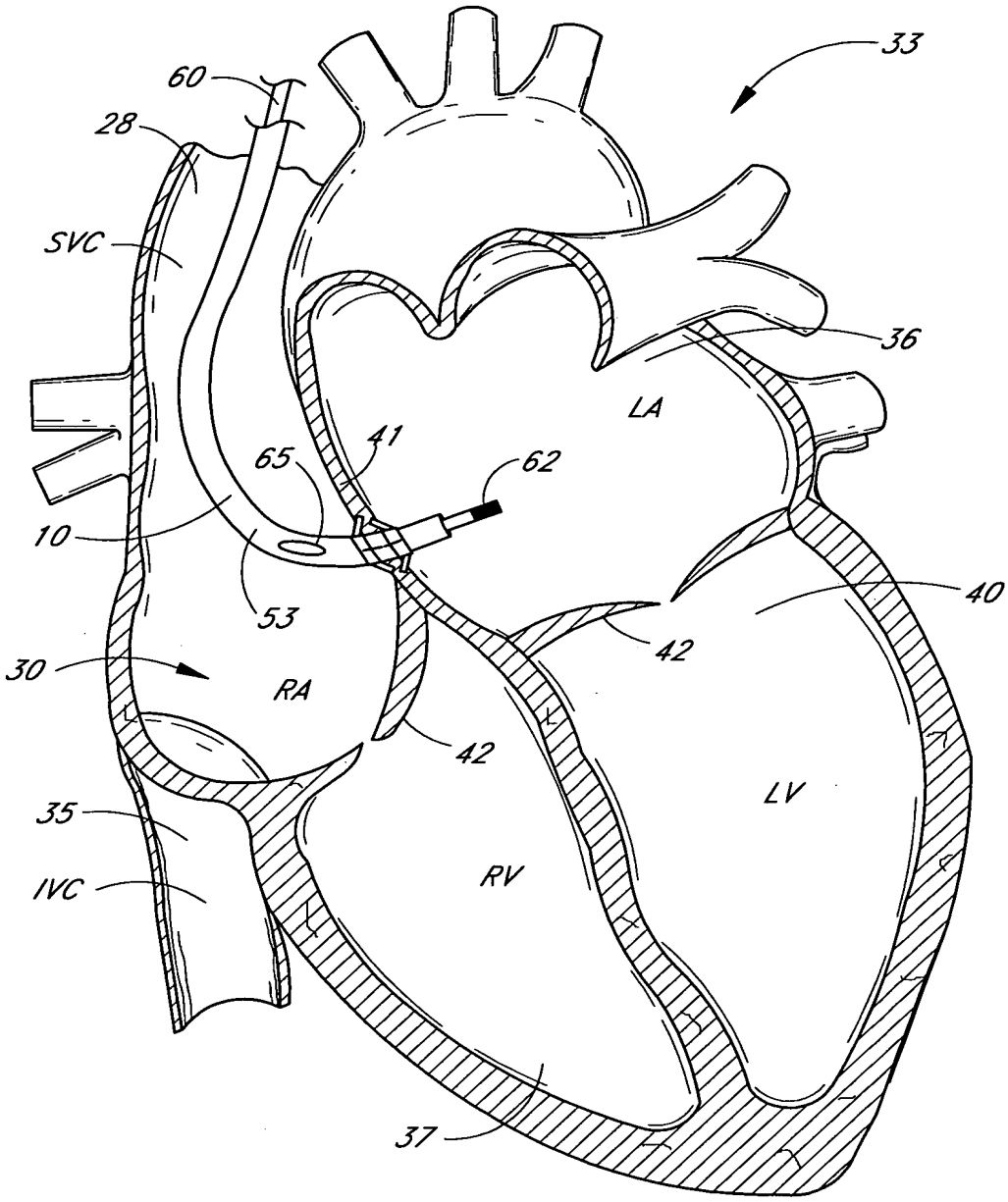


FIG. 14

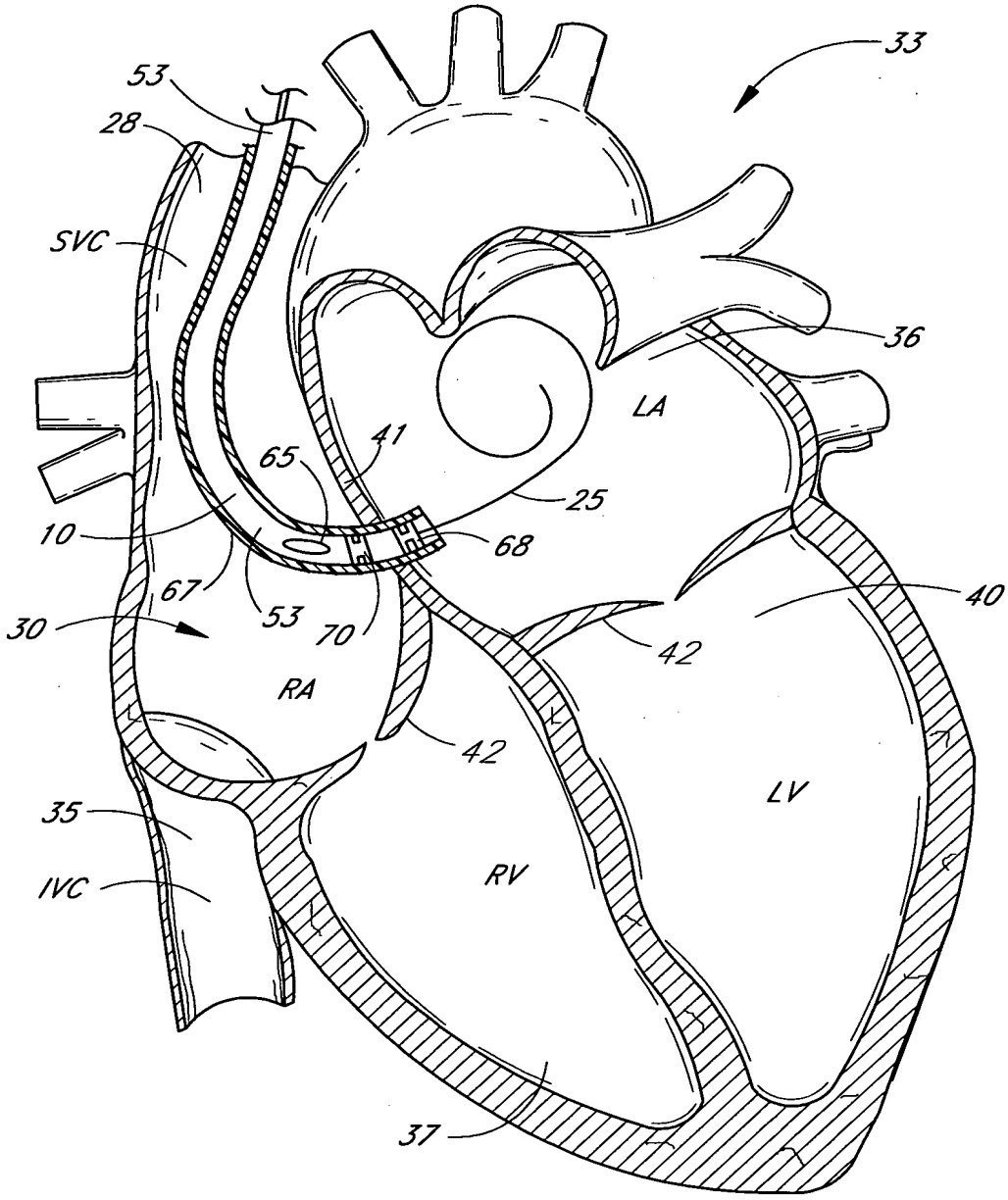

33
53
28
SVC
36
LA
41
65
25
10
68
67
53
70
30
40
42
RA
42
LV
35
IVC
RV
37

FIG. 15

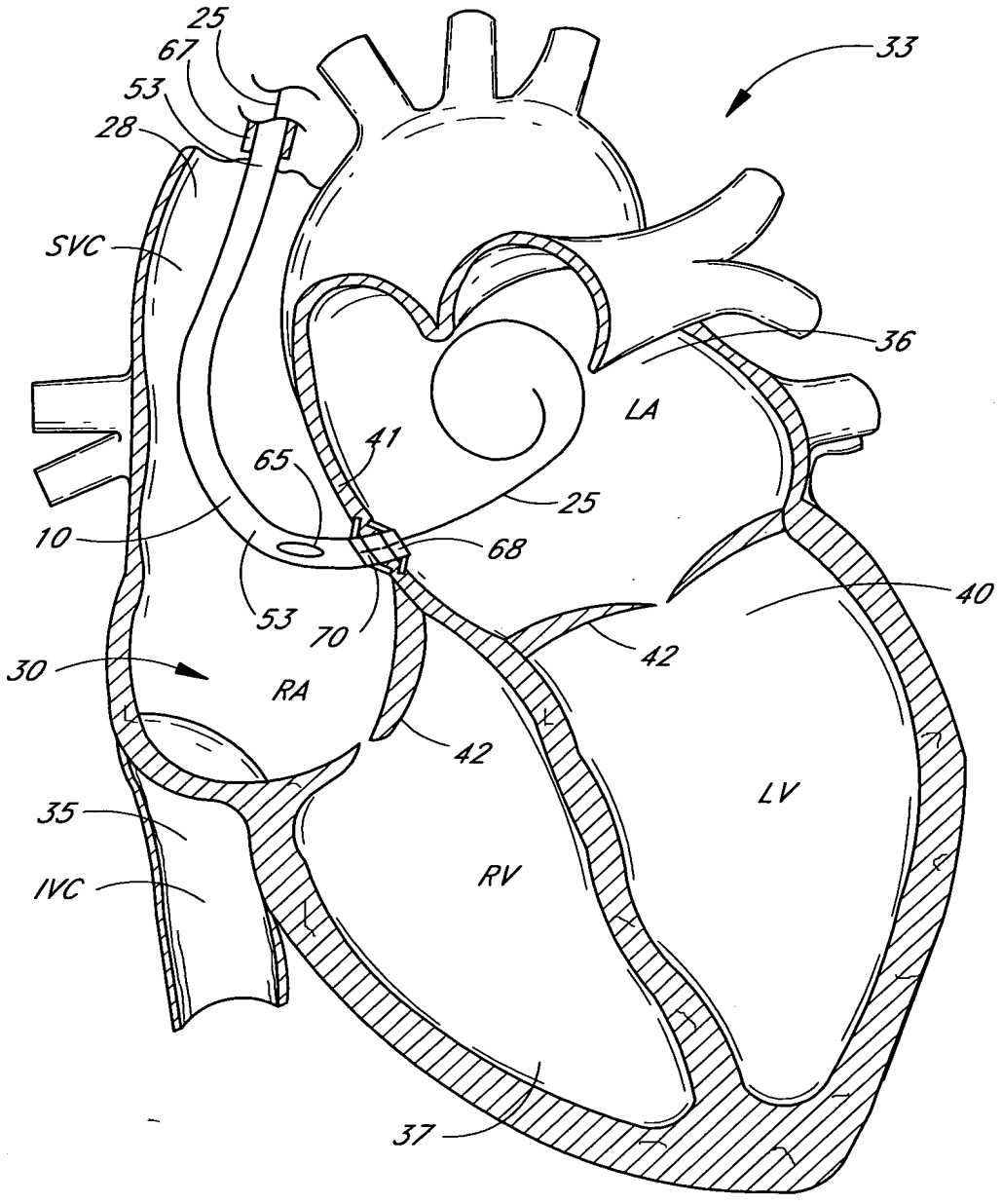

25
67
53
28
33
SVC
36
LA
41
65
25
10
68
40
53
70
42
30
RA
42
LV
35
RV
IVC
37

FIG. 16

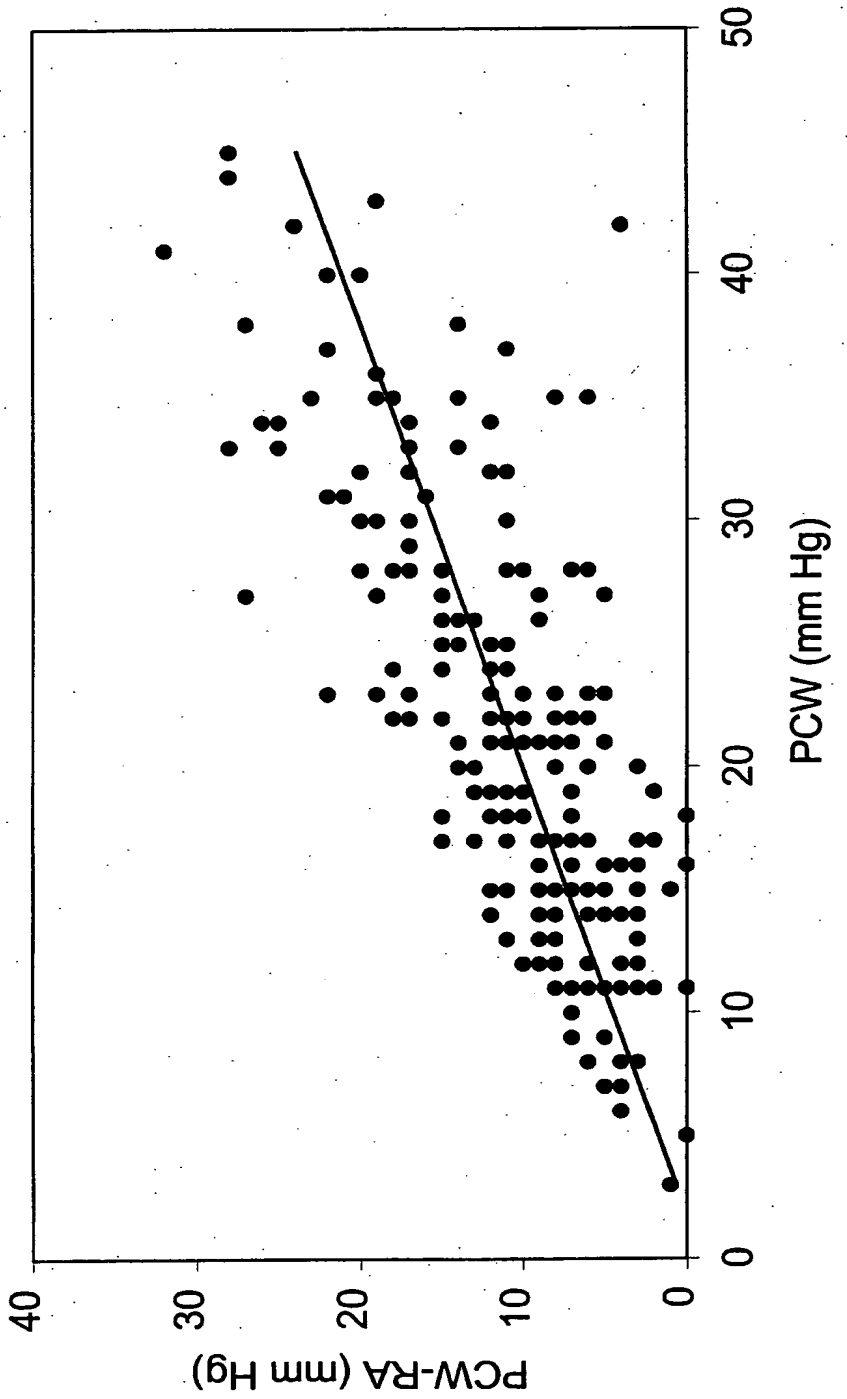


FIG. 17

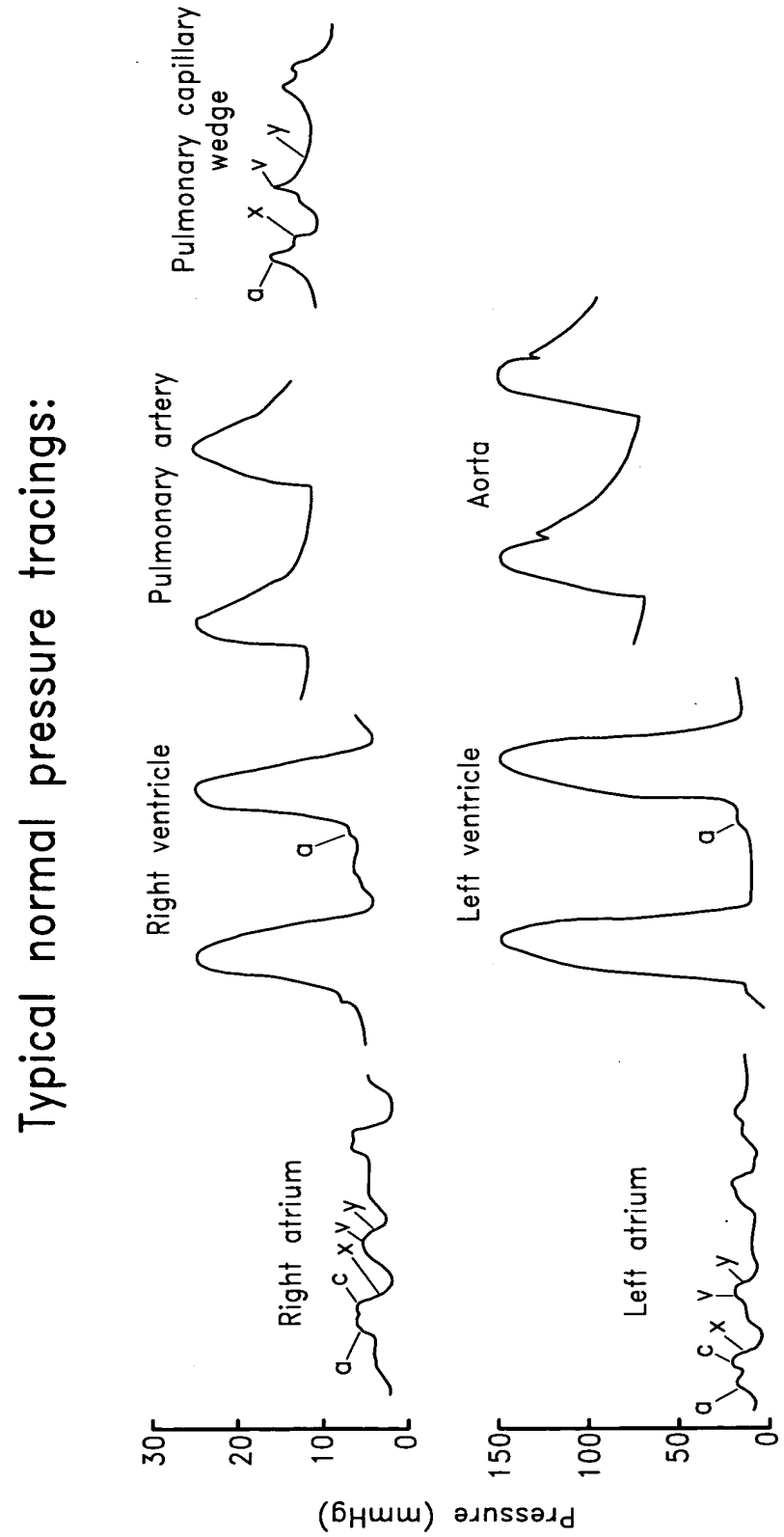

Typical normal pressure tracings:
Right ventricle
Pulmonary artery
Pulmonary capillary wedge
Right atrium
Left ventricle
Aorta
Left atrium
a
c
x
y
v
30
20
10
0
150
100
50
0
Pressure (mmHg)

FIG. 18

PRESSURES	Average (mm HG)	Range (mm HG)
Right atrium		
a wave	6	2-7
v wave	5	2-7
mean	3	1-5
Right ventricle		
peak systolic	25	15-30
end-diastolic	4	4-7
Pulmonary artery		
peak systolic	25	15-30
end-diastolic	9	4-12
mean	15	9-10
Pulmonary capillary wedge		
mean	9	4-12
Left atrium		
a wave	10	4-16
v wave	12	6-21
mean	8	2-12
Left ventricle		
peak systolic	130	90-140
end-diastolic	8	5-12
Central aorta		
peak systolic	130	90-140
end-diastolic	70	60-80
mean	85	70-105
VASCULAR RESISTANCES	MEAN ($dyne\text{-}sec\text{-}cm^{-5}$)	RANGE (dyne-sec-cm)
Systemic vascular resistance	1100	700-1600
Total pulmonary resistance	200	100-3000
Pulmonary vascular resistance	70	20-1300

FIG. 19

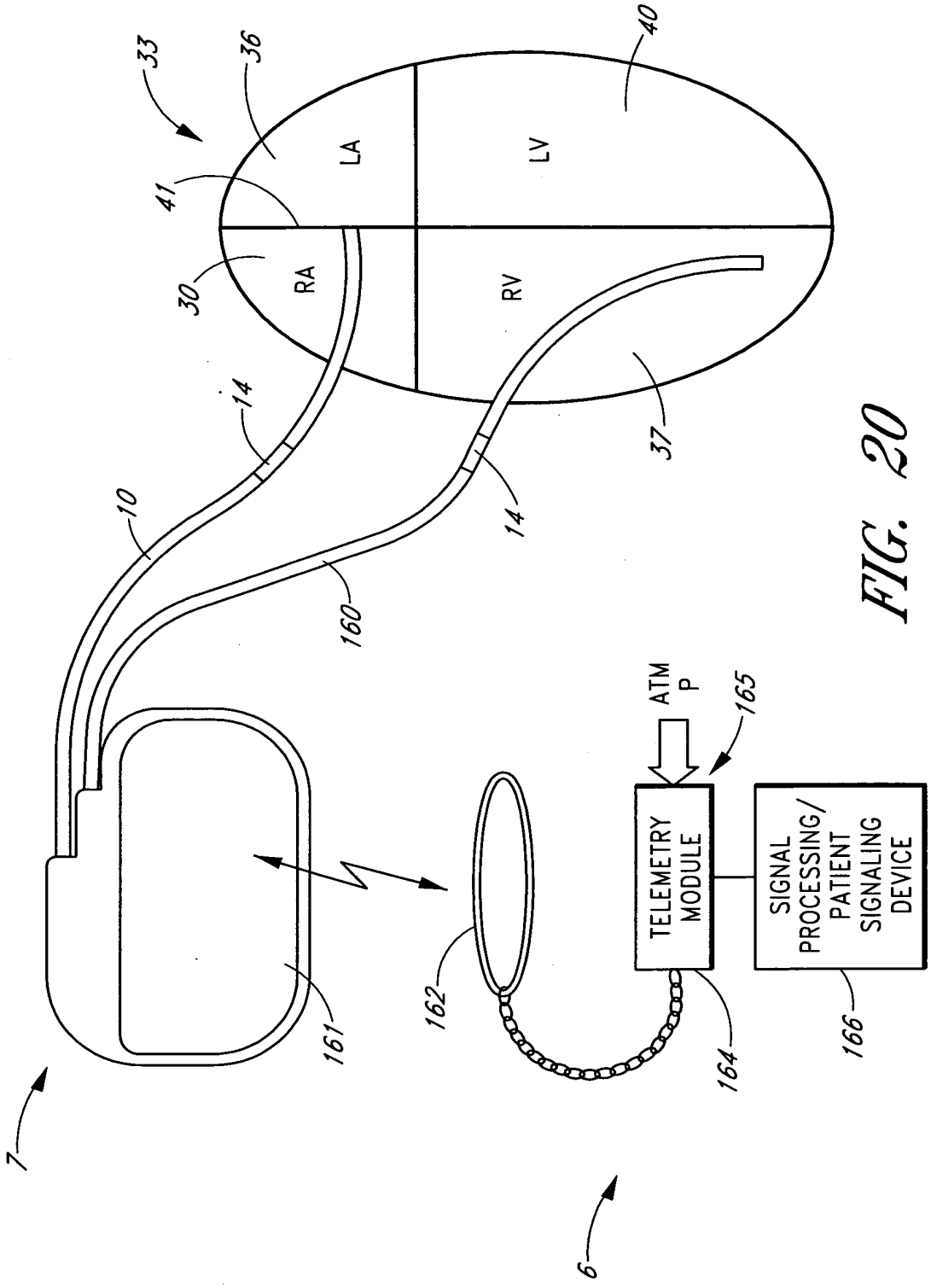

33
36
40
41
LA
LV
30
RA
RV
14
37
10
14
160
ATM
P
165
TELEMETRY
MODULE
SIGNAL
PROCESSING/
PATIENT
SIGNALING
DEVICE
162
161
164
166
7
6

FIG. 20

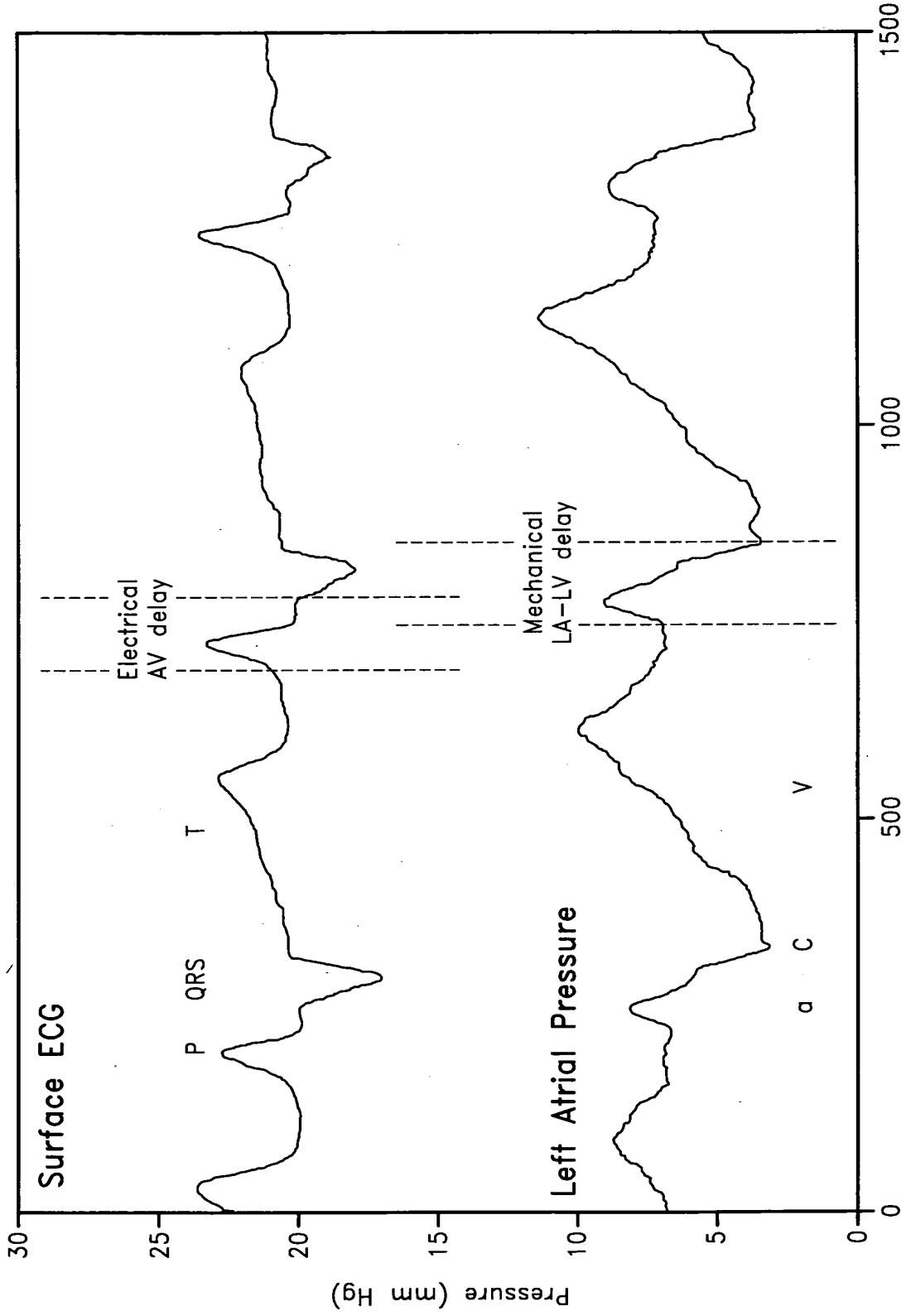

Surface ECG
P QRS T
Electrical
AV delay
Left Atrial Pressure
a C V
Mechanical
LA-LV delay
Pressure (mm Hg)
30
25
20
15
10
5
0
0
500
1000
1500

FIG. 21

FIG. 22

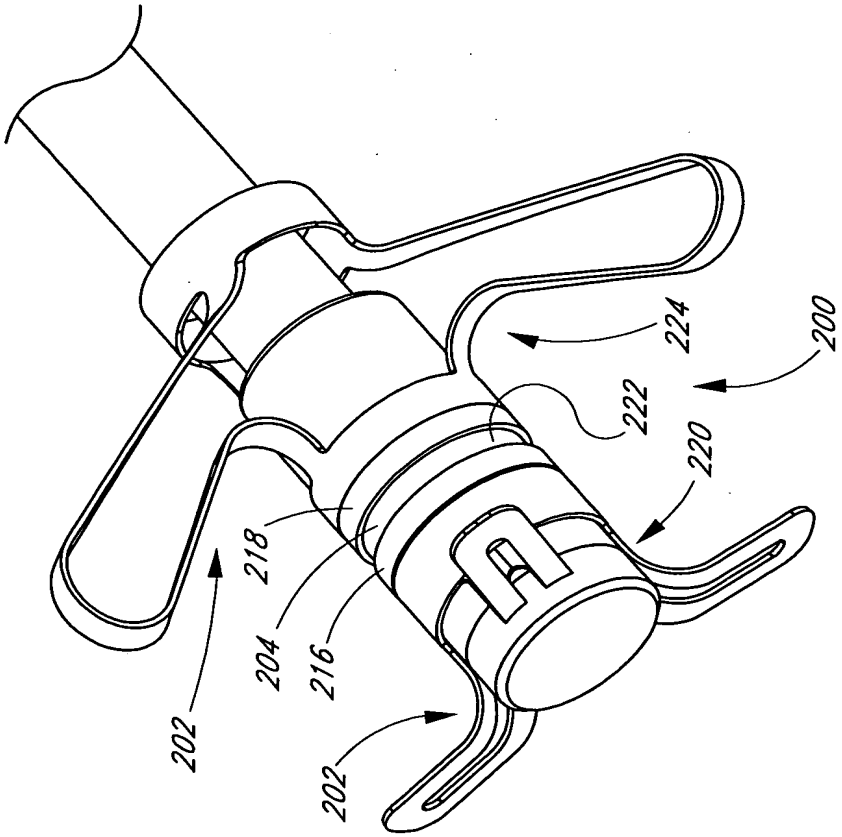
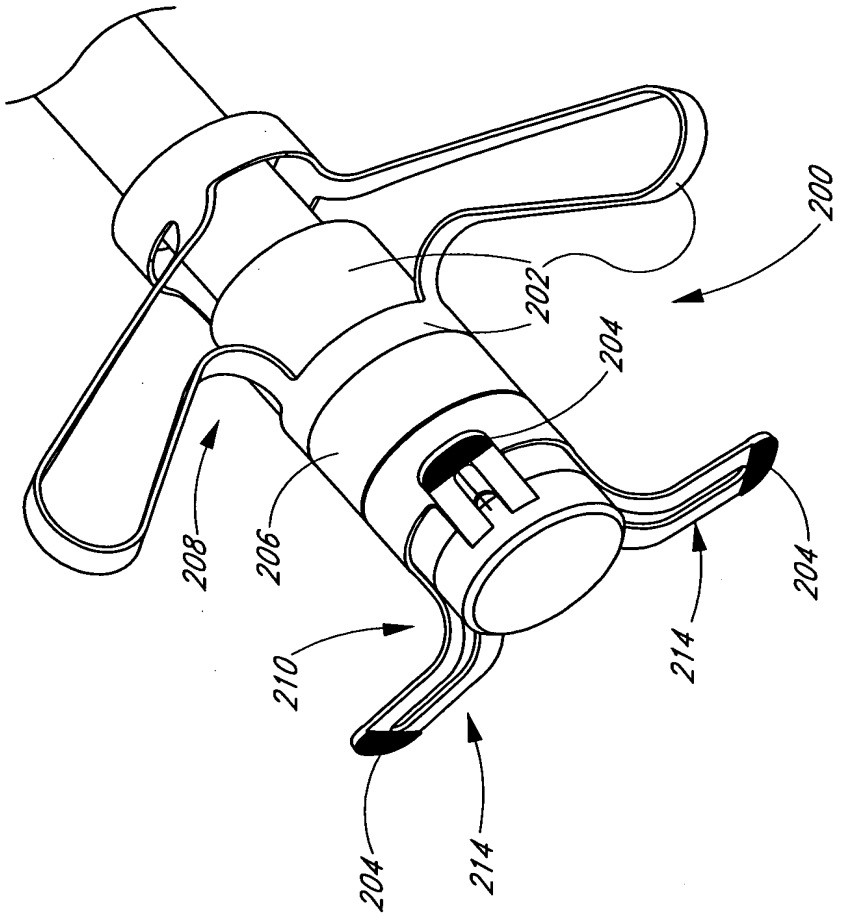


FIG. 23



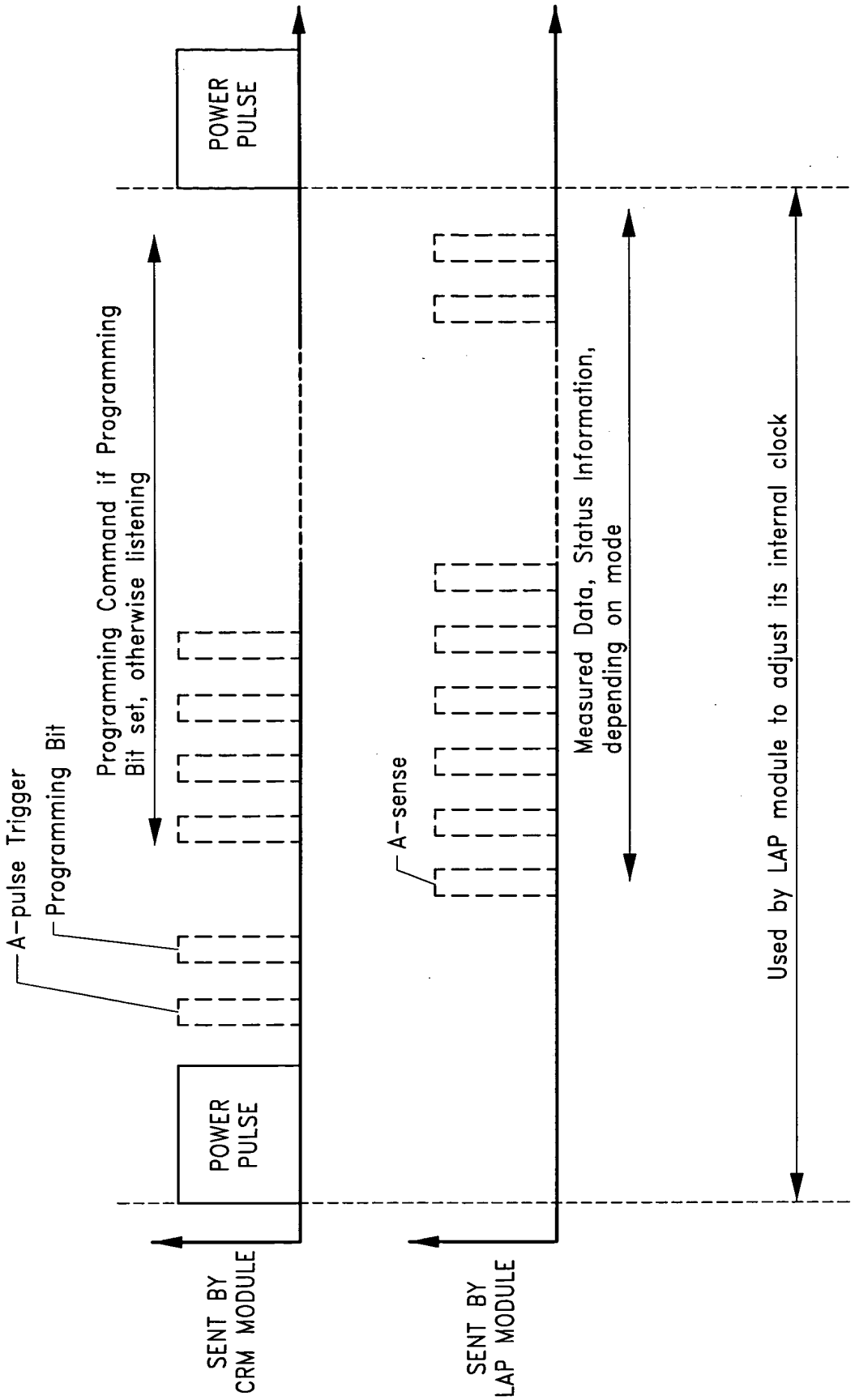

POWER PULSE
POWER PULSE
A-pulse Trigger
Programming Bit
Programming Command if Programming Bit set, otherwise listening
A-sense
Measured Data, Status Information, depending on mode
Used by LAP module to adjust its internal clock
SENT BY CRM MODULE
SENT BY LAP MODULE

FIG. 24

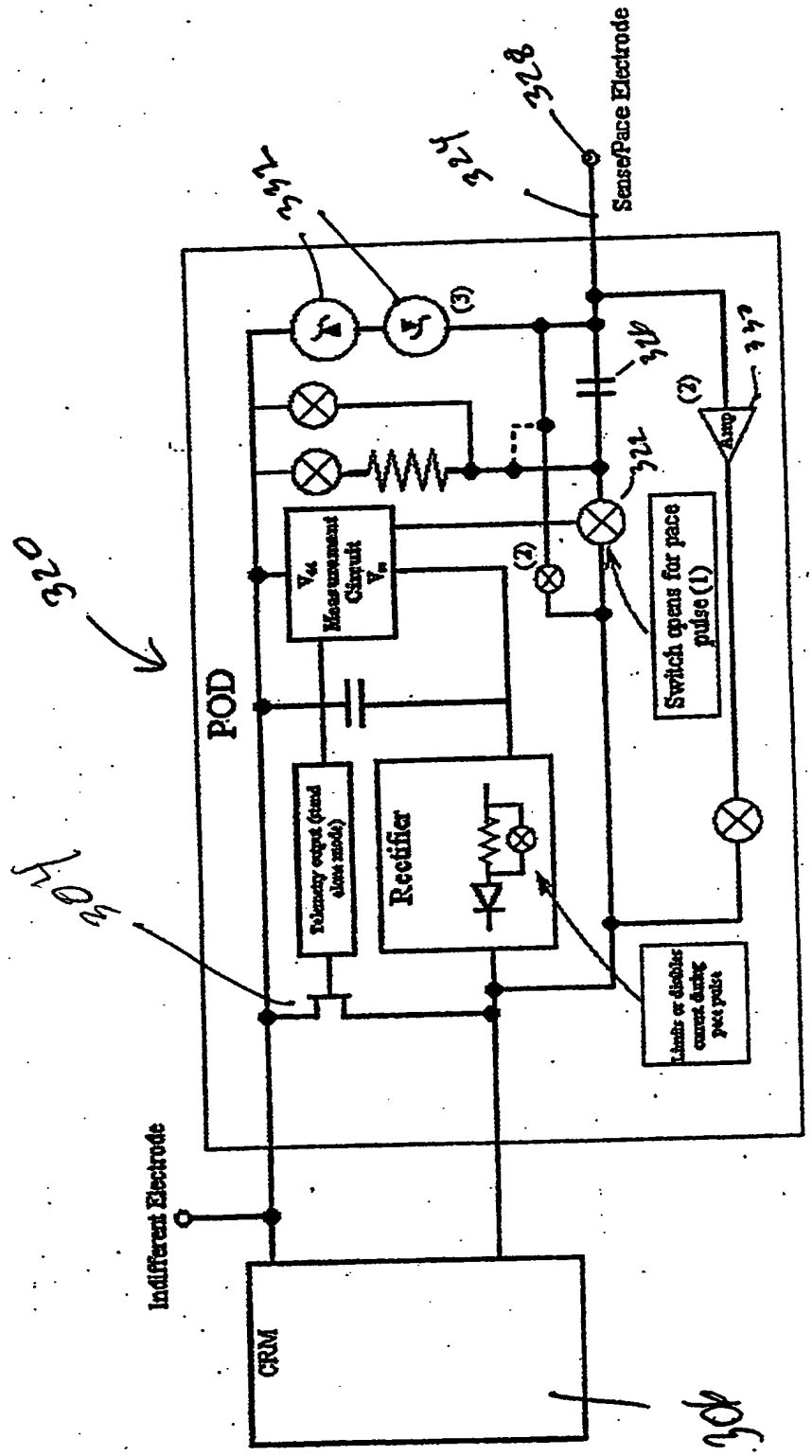

320
POD
Sense/Pace Electrode
Switch opens for pace pulse (1)
Amp
Rectifier
Telemetry output (fixed data mode)
Limits or disables current during pace pulse
Indifferent Electrode
CRM

FIG. 25

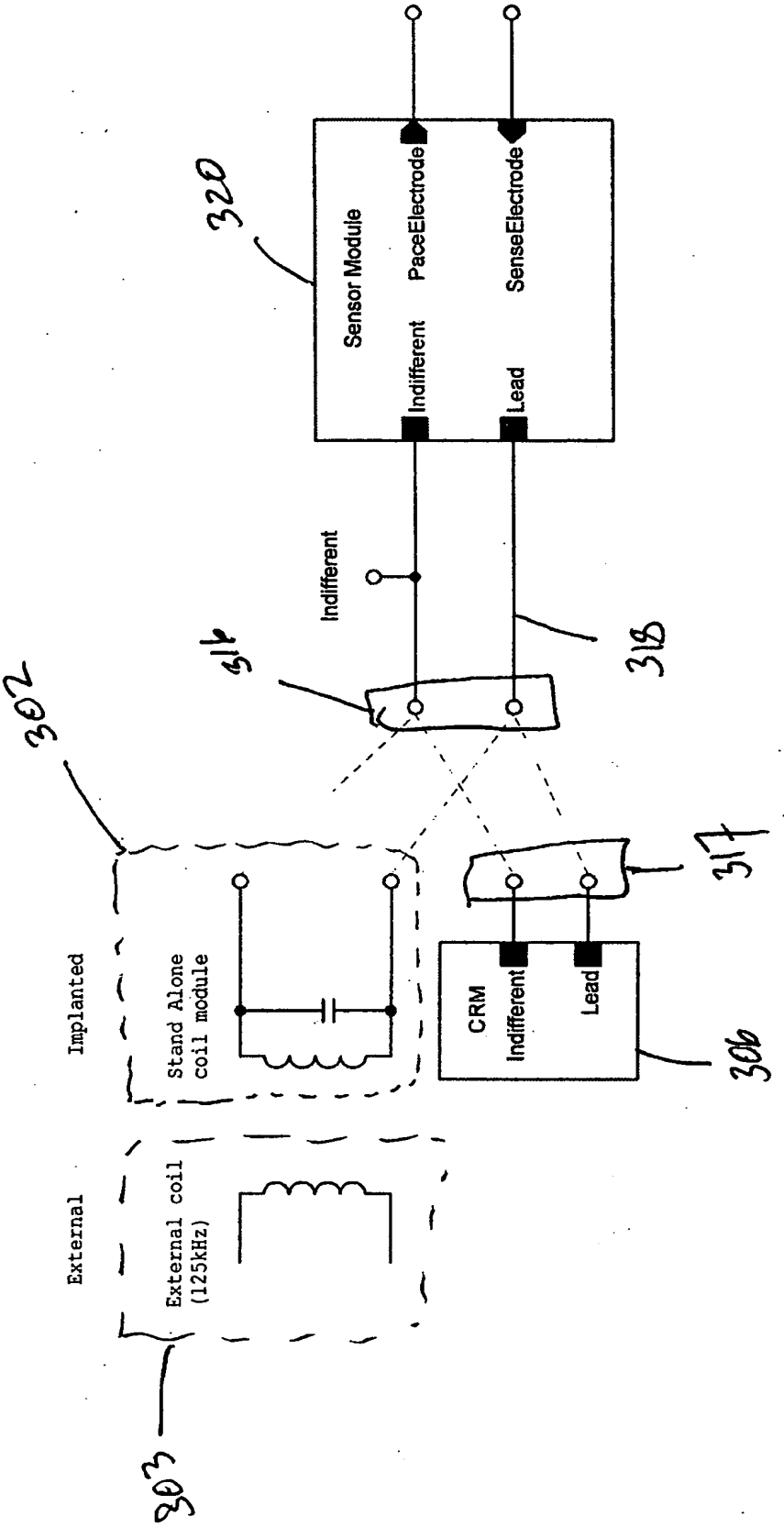

320
Sensor Module
PaceElectrode
SenseElectrode
Indifferent
Lead
Indifferent
316
318
302
317
Implanted
Stand Alone
coil module
CRM
Indifferent
Lead
306
External
External coil
(125kHz)
303

FIG. 26A

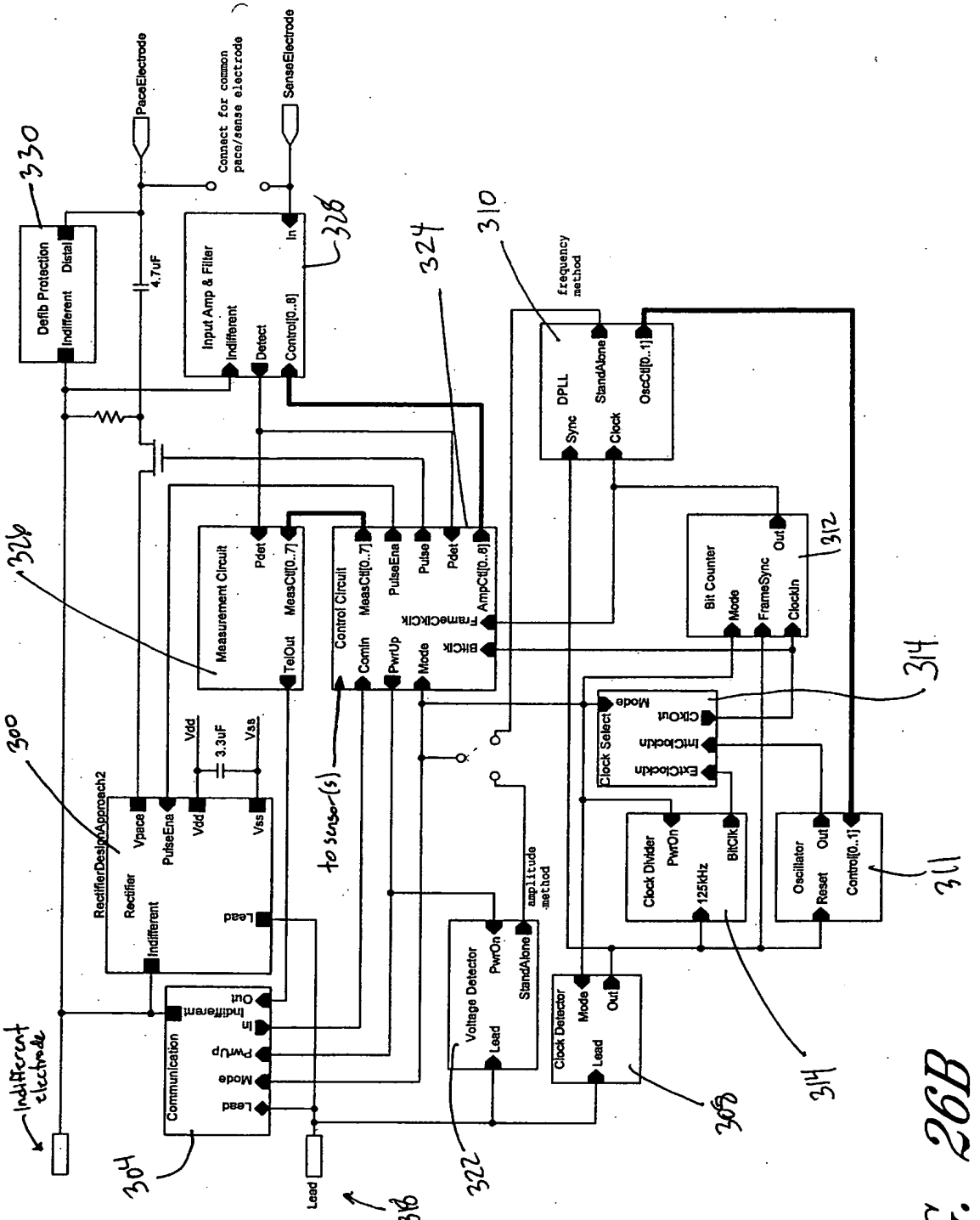

330
PaceElectrode
Connect for common pace/sense electrode
SenseElectrode
Defib Protection
Distal
Indifferent
4.7uF
Input Amp & Filter
Indifferent
Detect
Control[0..8]
In
328
324
310
frequency method
DPLL
Sync
StandAlone
Clock
OscCtl[0..1]
326
Measurement Circuit
Pdet
MeasCtl[0..7]
TelOut
Control Circuit
MeasCtl[0..7]
PulseEna
Pulse
Pdet
AmpCtl[0..8]
FrameClkClk
BitClk
ComIn
PwrUp
Mode
Bit Counter
Out
Mode
FrameSync
ClockIn
312
314
Clock Select
Mode
ClkOut
IntClockIn
ExtClockIn
300
Vdd
3.3uF
Vss
RectifierDesignApproach2
Rectifier
Vpace
PulseEna
Vdd
Vss
Indifferent
Lead
to sensor(s)
Clock Divider
PwrOn
125kHz
BitClk
Oscillator
Out
Reset
Control[0..1]
311
amplitude method
Voltage Detector
PwrOn
StandAlone
Lead
Clock Detector
Mode
Out
Lead
Communication
Out
Indifferent
In
PwrUp
Mode
Lead
Indifferent electrode
304
Lead
318
322
308
314

FIG. 26B

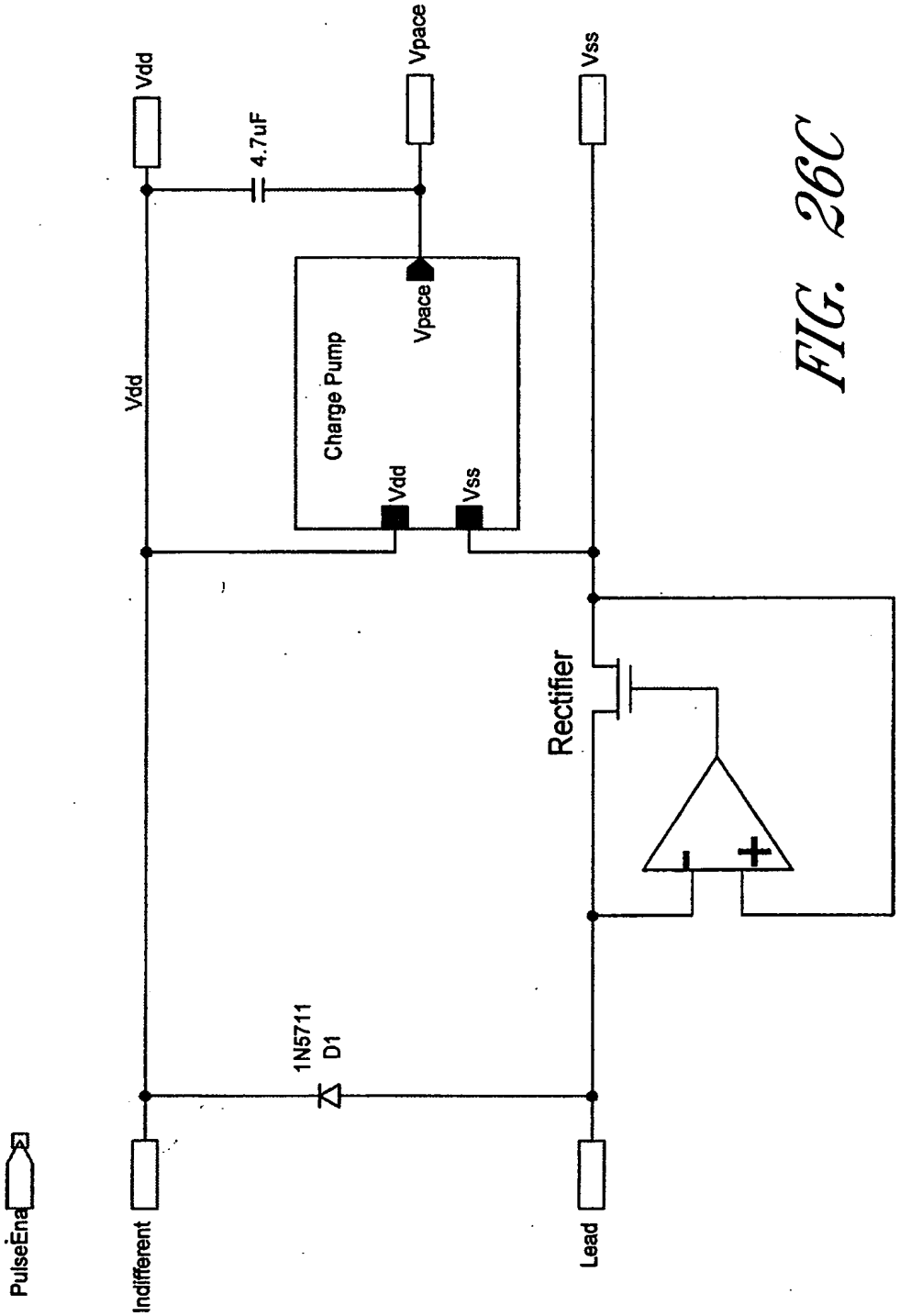

Vdd
4.7uF
Vpace
Vss
Vpace
Charge Pump
Vdd
Vss
Vdd
Rectifier
1N5711
D1
PulseEna
Indifferent
Lead

FIG. 26C

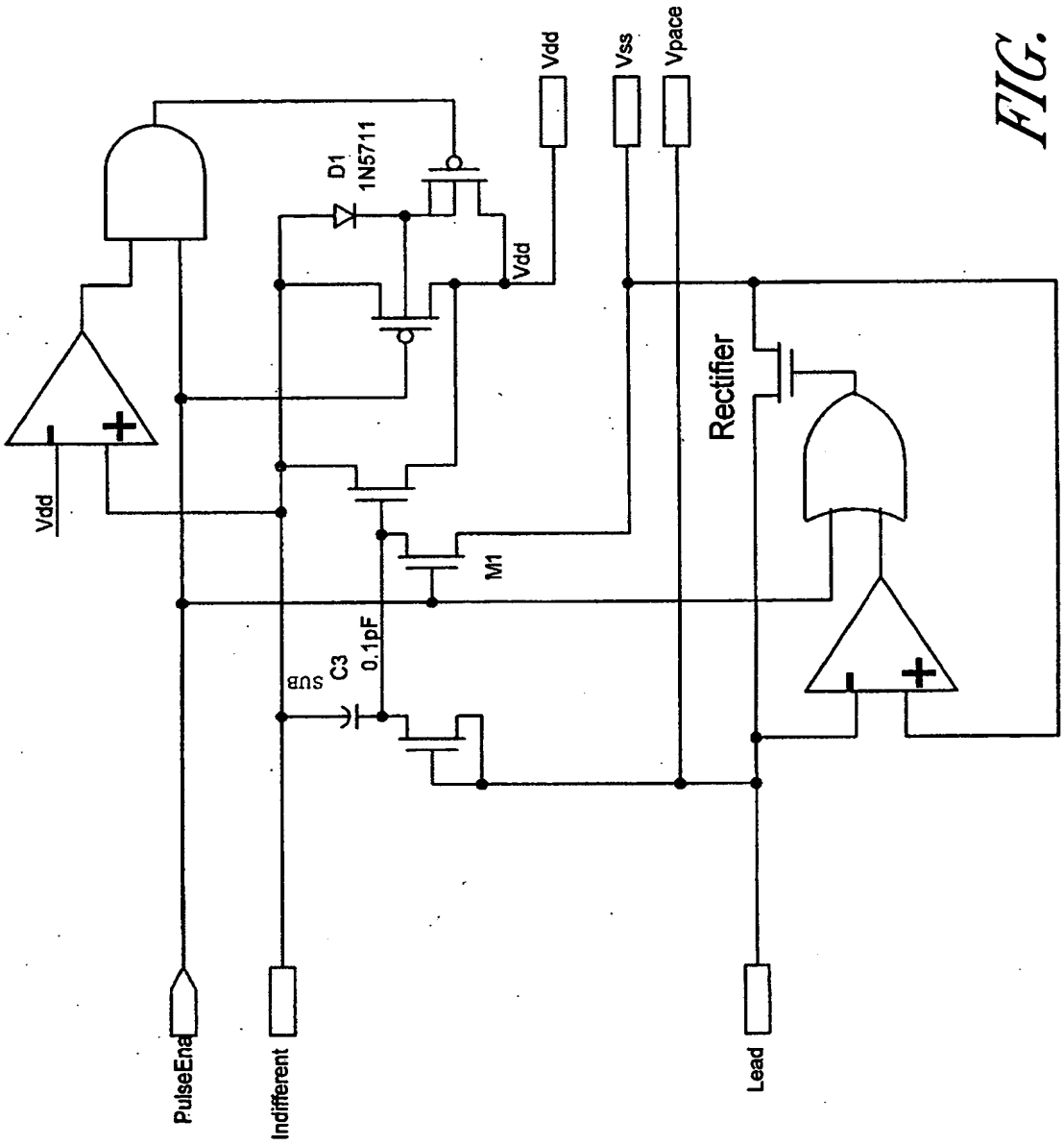

Vdd
Vss
Vpace
D1
1N5711
Vdd
Vdd
Rectifier
M1
C3
0.1pF
sub
PulseEna
Indifferent
Lead

FIG. 26D

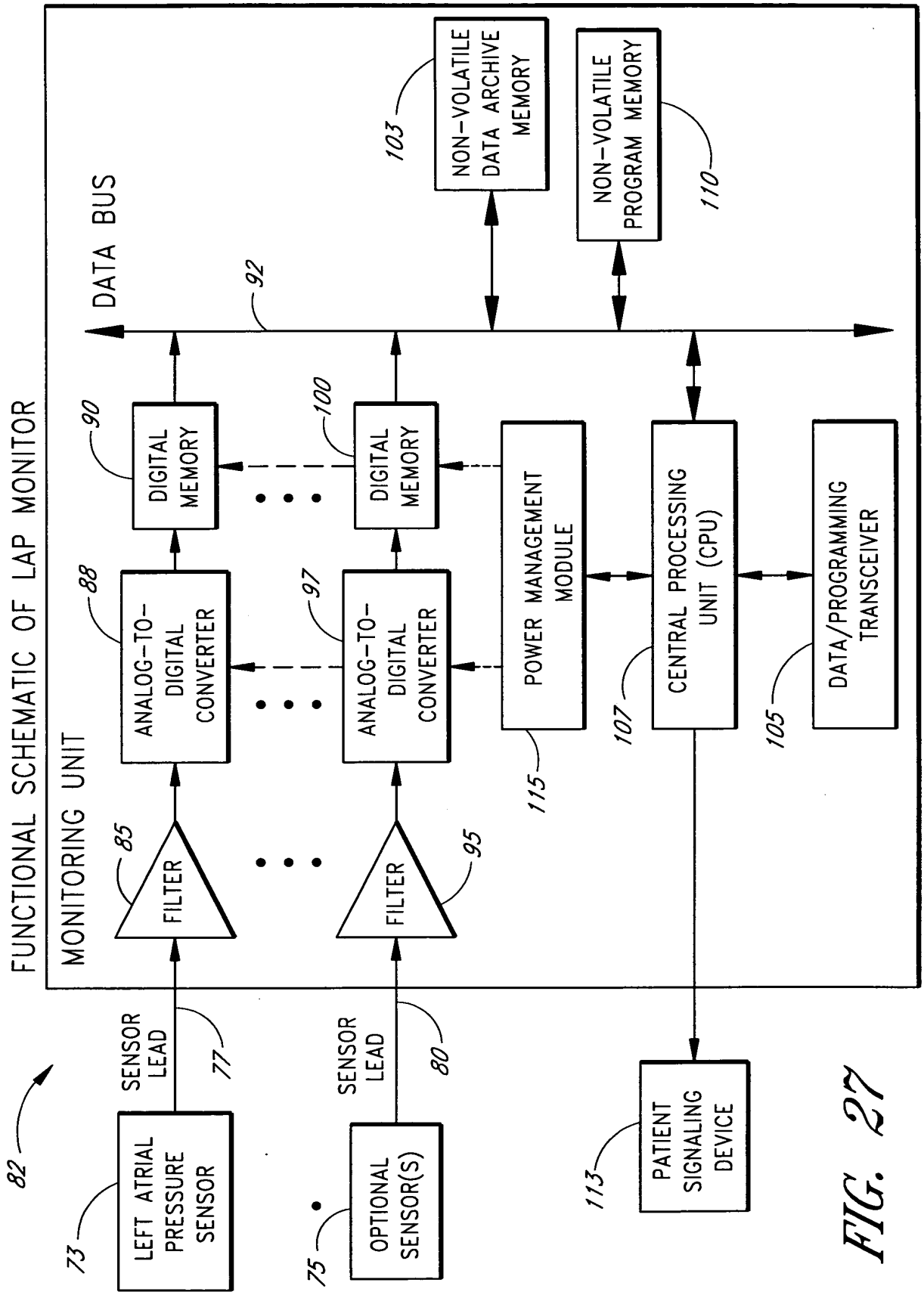

FUNCTIONAL SCHEMATIC OF LAP MONITOR
MONITORING UNIT
DATA BUS
92
NON-VOLATILE DATA ARCHIVE MEMORY
103
NON-VOLATILE PROGRAM MEMORY
110
DIGITAL MEMORY
90
DIGITAL MEMORY
100
ANALOG-TO-DIGITAL CONVERTER
88
ANALOG-TO-DIGITAL CONVERTER
97
POWER MANAGEMENT MODULE
115
CENTRAL PROCESSING UNIT (CPU)
107
DATA/PROGRAMMING TRANSCEIVER
105
FILTER
85
FILTER
95
SENSOR LEAD
77
SENSOR LEAD
80
82
LEFT ATRIAL PRESSURE SENSOR
73
OPTIONAL SENSOR(S)
75
PATIENT SIGNALING DEVICE
113

FIG. 27

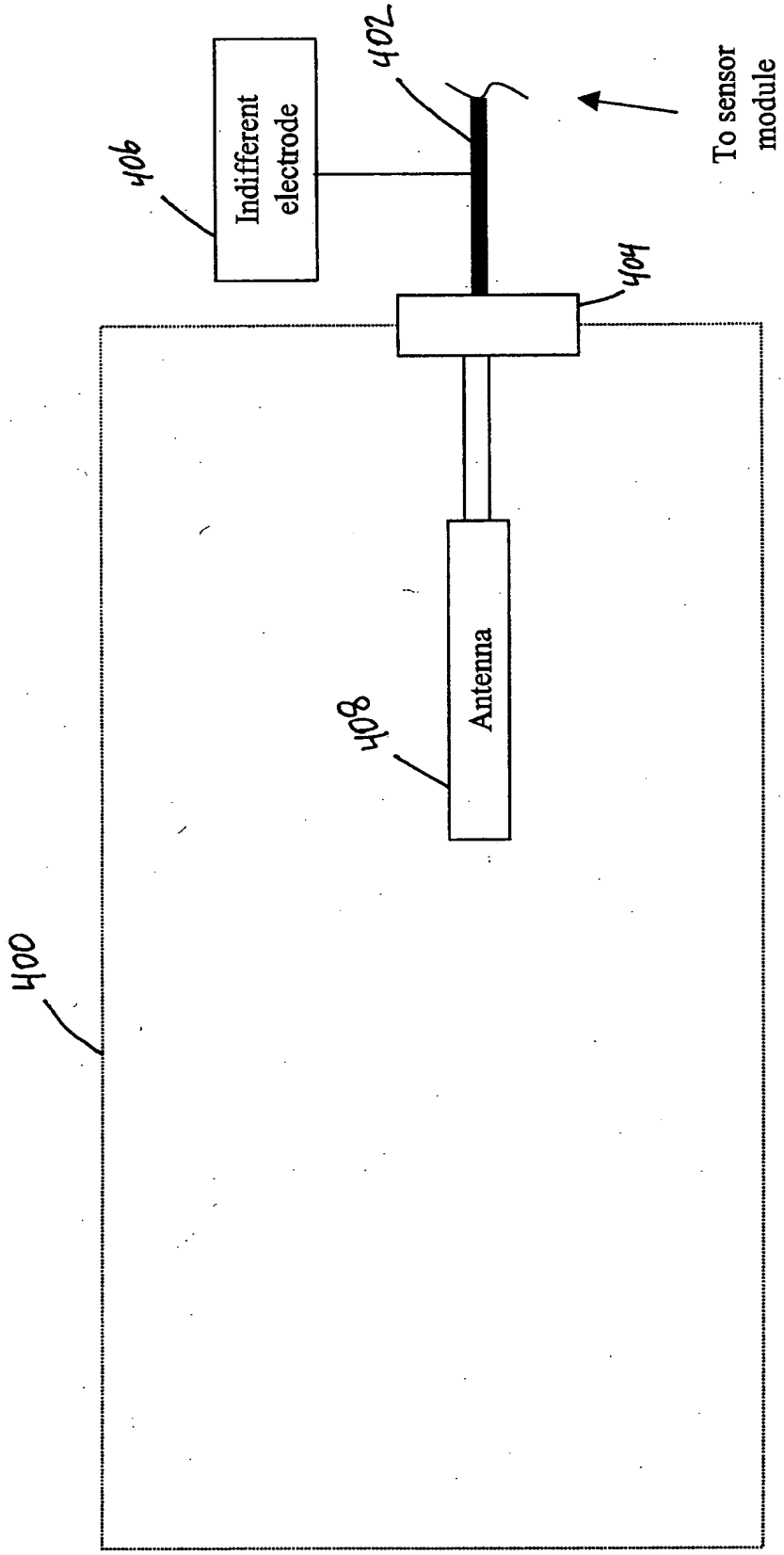

402
406
Indifferent electrode
To sensor module
404
Antenna
408
400

FIG. 28

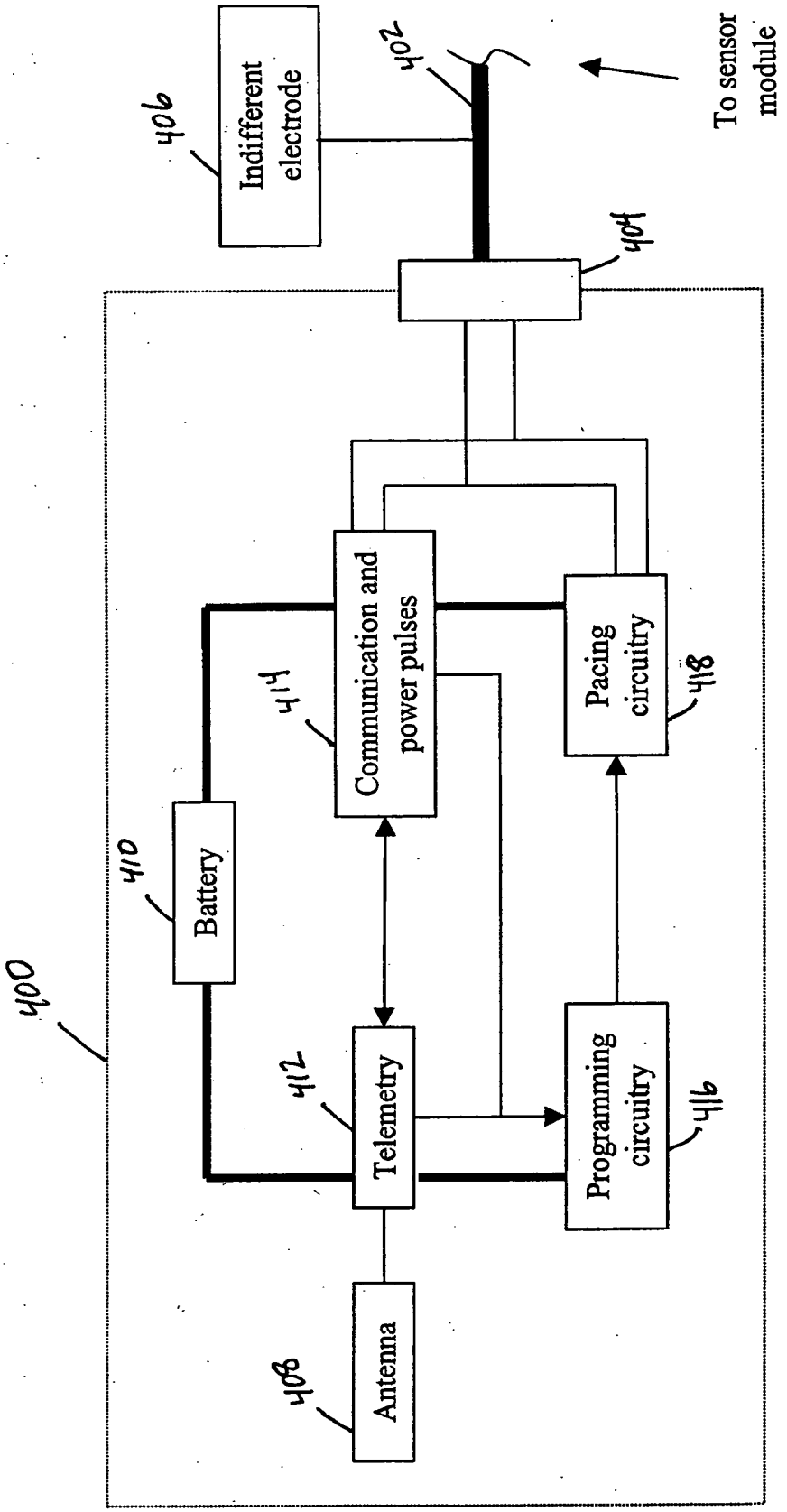

Indifferent electrode
406
402
To sensor module
404
Communication and power pulses
414
Pacing circuitry
418
Battery
410
400
Telemetry
412
Programming circuitry
416
Antenna
408

FIG. 29